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Industrial Hygiene

ASSOCIATION

Quarterly

VOLUME 15, NUMBER 2
JUNE, 1954

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Volume 15 JUNE, 1954 Number 2

NOW WE ARE FIFTEEN 111
Frank A. Patty

CATALYTIC COMBUSTION—EVALUATION OF CATALYSTS 119
Amos Turk, Ph.D.

MEDICAL RESEARCH PROGRAM IN INDUSTRY 124
Robert E. Eckardt, M.D.

NOISE, NOXIOUS OR NICE 127
Rear Admiral Lamont Pugh (MC) USN

EXHAUST RATES FOR DUST CONTROL—THEORETICAL REQUIREMENTS IN BULK MATERIAL HANDLING SYSTEMS 132
W. C. L. Hemeon

FIELD STUDIES OF THE DIFFUSION OF AEROSOLS 136
Morton L. Barad and Bernard Shorr

SAFE HANDLING PROCEDURES FOR COMPOUNDS DEVELOPED BY THE PETRO-CHEMICAL INDUSTRY 141
Charles Henri Hine, M.D., Ph.D., and N. W. Jacobsen

DUST SAMPLING BY THERMAL PRECIPITATION 145
I. G. Poppoff

AMERICAN INDUSTRIAL HYGIENE ASSOCIATION

Fifteenth Annual Meeting 152

President's Page 153

Selected Titles and Abstracts from Foreign Exchange Journals 154

News of the Local Sections 155

In the News 156

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Now We Are Fifteen

The Cummings Memorial Lecture

FRANK A. PATTY, Head, Industrial Hygiene Department
Research Laboratories Division
General Motors Corporation, Detroit

THERE ARE SEVERAL people here tonight who got together in a hotel room in Cleveland fifteen years ago and laid the foundation of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION. The occasion was an occupational health conference not too different from the one we have enjoyed this week. Although we were then quite young, our parentage was of the best, our birth auspicious, and our objective sound.

Frank A. Patty

Our growth and accomplishments since that time have justified all the dreams and work a great many people have put into the united effort to make our organization grow and develop. Because AIHA was conceived, born, and has grown, there has been much benefit to all of our members regardless of their professional background, to untold thousands of industrial employees, to industry itself, and to our country. Now that we are fifteen, and presumably approaching maturity, it appears appropriate that we pause tonight to look about us, take stock of our accomplishments, and consider possible readjustment of our sights.

First, there is the responsibility of *recognition of environmental causes and sources of illness in industry.* Wherever non-specific illness in industry has reached the attention of industrial hygienists and industrial physicians in recent years, their cooperative efforts have been successful in establishing the origin of the illness. So, in that respect, we may consider ourselves to be at least approaching maturity. This, however, does not indicate that all possible sources have been recognized—merely, that wherever illness may develop in industry at any future time, if it is of environmental origin, we probably will recognize the cause and source.

The evaluation of the cause and source of industrial illness has become a rather well established routine and, although improvements in sampling and analytical techniques are constantly occurring, this phase of the work may also be regarded as reasonably mature.

The control of these causes and sources of illness has received the chief attention in recent years. Nearly every successful industrial hygiene unit today has men on the staff or in close association who can plan and develop control measures that are engineeringly and economically sound and applicable to the control of almost any factually established exposure. In the control aspects also, we are approaching maturity.

Does this mean that we should be alert for signs of decline and obsolescence, that we should guard against the day when everything has been done and there are no more environmental problems in industry? In other words, are we in danger of working ourselves out of a job? The question has been asked before and sometimes answered in the affirmative, but such an answer is not born of sound thinking. The only

Donald E. Cummings Memorial Lecture, presented at the Fifteenth Annual Conference, AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, Chicago, April 29, 1954.

way we can work ourselves out of a job is by failing to produce and distribute factual information to the people in industry who are in a position to apply it to improving the industrial environment. Successful management is always receptive to sound environmental improvements.

To date we have been concerned largely with the more obvious environmental factors that adversely affect employees—factors that can cause readily recognizable ill effects. Until this field is more adequately covered by making established facts more widely available and understood by management we cannot logically consider our profession to be mature, even in these basic respects.

SUPPOSE we consider some territory that is not so well charted: First, let's talk about *noise*. All of us recognize noise to be an industrial problem, but until recently we rather complacently regarded 120 decibels as the hygienic limit below which employees were safe from harm, and the area between 120 and 130 as something to be frowned upon. Now we are awakening to the fact that studies of industrial noise and its effect upon hearing have not been sufficiently analytical and thorough to satisfactorily define the areas for recommended safe practice. Meantime, industry has been rapidly expanding in recent years, employing more men, and using more and noisier machines. There are clearly two things we can and should do on this problem without delay. First, we should measure and analyze existing exposures. Second, we should attempt to abate the highest levels and, in fact, any noise that seriously interferes with speech. The results of environmental noise analyses should be made available to our medical associates and we should encourage correlation of these results with pre-employment and periodic examinations of employees for hearing loss. Even though noise evaluation is difficult, the medical phase of the problem is much more complex than the environmental measurements. It is complicated by such factors as the shortcomings of pure tone audiometry and methods of translating the results into terms of disability, hearing loss due to age, the variation in testing procedures such as length of time away from the job before test, and the fact that cases are recorded where hearing loss has been found to be partially reversible after extended periods away from a noisy environment. Research into the effects of exposure to noise is difficult in industry, especially conducting hearing tests of employees at a time when noise fatigue or temporary hearing loss is not an important factor. Even making the examinations before the start of the work week poses serious production problems that must be considered.

We can, however, work and progress immediately in the field of noise reduction to the advantage of everyone concerned. We cannot expect results if we merely tell production people that they should or must reduce noise. Here is one of the best opportunities for salesmanship. The man who will have to do the noise reduction job in the plant is likely to be the plant engineer. If his management tells him to get busy and do something, he is more or less at the mercy of the suppliers of acoustic materials unless we come to his rescue. He needs a great deal of basic information in order to avoid wasting time and money. He cannot acquire these things overnight by reading, or even by listening to the right people; but if he can see photographs of installations that have done a job or, better yet, if he can hear and see a demonstration of some of the basic control methods he can quickly acquire a working knowledge of the principles involved. Immediately he is interested because he understands how it works and can do some experimenting on his own.

THE SITUATION regarding industrial noise, confusing and chaotic as it is, can be no more so than the field of *air pollution*. No industrial hygiene organization today can ignore air pollution because the contaminants in the air of the community are the baseline upon which any indoor air contamination studies or control programs must be built. As in the case of industrial noise, much of the confusion stems from early impulses in both fields to "pass a law" to control these unwanted contaminants before knowing their nature, their source, or how to control them. The public and public officials caught in the stampede of interested persons have been guided more by emotions and ambitions than by facts. We, in the in-

dustrial hygiene field are particularly well equipped to help establish order out of this chaos. We have a background of experience in proceeding in an orderly manner to collect statistically sound data to establish facts before rushing into print. Many industrial sources of pollution have been highlighted and controlled. Some industries, because of the difficulty and cost of controls, have their very existence threatened. Cities that have been successful in noticeably improving the appearance of their atmospheres required the cooperation of their citizenry in abating smoke. On the other hand, more than one of the cities said to be competing for the top of the list as the country's dirtiest have caused industry to spend huge sums for air cleaners without noticeable improvement in visibility or reduction of the quantity of solid air-borne particles. The questions of what this pollution is and whether it comes from unrecognized sources within these cities or is carried in by prevailing winds from more distant sources require solution.

As an immediate practical approach we can urge the use of any and all economically feasible air-cleaning methods wherever factual information establishes the need. Those of us who are in industry can and should know the nature and extent of our significant airborne plant effluents in terms of weight, chemistry and particle size. We can cooperate in community studies to determine the nature and extent of the community problem. In such studies we can and must insist that they be conducted in a technically sound manner free of emotional and political pressure. In order to obtain the support of industry in community studies it is necessary that it be provided with assurance that hasty uneconomic controls, which might jeopardize its very existence in a competitive market, will not be imposed. In any study of pollution arising from multiple sources it is logical and sound to recognize and control the major sources first in order to find the more obscure ones. The degree of control required should be tempered by economic considerations and a practical approach to the entire problem. Much technical information needs to be developed including more on the toxicity and synegistic effects of pollution. Immature statements of the health aspects involving unreliable morbidity data and hasty half-truths about the nature and source of pollutants should be discourged in order to avoid more confusion and public hysteria. We industrial hygienists cannot remain on the sidelines in this free-for-all, but must accept a share of the responsibility.

ANOTHER FIELD in which we have done little, and yet it has great opportunities for environmental improvement is the control of *radiant heat contamination* by means of reflective surfaces. Like noise, the subject of heat also lends itself well to the demonstration technique. In some instances where control by ventilation is being practiced, results can be improved by the use of reflectors and at a considerable saving in cost. This may be true around furnaces, in drop forging, in hot castings handling, metal pouring and other occupations.

There are many opportunities for *research* in industrial hygiene. By and large research is best done at research centers, universities and colleges, or by chemical manufacturers studying the pharmocology and toxicity of their products. All industrial hygiene units need to do some research on sampling and analysis and we should never overlook an opportunity to work with the medical group in an environmental study.

A FIELD of research and development that more and more people are turning their thoughts toward is one frequently called *human engineering*. This is concerned with the proper design of industrial machines, process equipment and work facilities in order to avoid undue stress upon industrial employees. There is evident need for developing such a field of specialized engineering. The principles and laws that govern man's response to external stress and determine his capabilities and limitations to withstand stress form the basis for such specialization, just as the chemical and physical laws provide the foundations for existing branches of engineering. As work situations become more complex and craftsmanship yields to machine operation, the employee is operating at a different physiological and psychological level than formerly. The need for the best possible adjustment between the man and his job is in-

creasing. Engineers responsible for the design of industrial process equipment need a systematic basis for evaluating the human factor. Sound utilization of anatomical, physiological and psychological facts should replace empirical procedures for meeting requirements in the analysis and design of machines and work situations. Industrial hygienists have certain qualifications that warrant their interest in this field. This does not mean that we should rush in like a bull in a china shop and profess to have extensive knowledge that will prove immediately useful. It does mean that because of our considerable experience in combining and integrating knowledge, principles and laws from both the physical and biological sciences for dealing with human problems, we can serve as a useful link in the chain. Our experience in operating between the fields of physical and biological science is fairly unique and should provide an effective means for bridging the gap between engineering and physiology or psychology in the further development of human engineering. If quantitative values are going to be developed to replace some of the current opinions regarding capabilities and limitations, we must at least be aware of their source and origin and we should be prepared to participate in their development. Opportunities to pursue the subject with people responsible for methods engineering and machine design should be encouraged.

But we are concerned here with assessing our progress toward maturity. The *insurance* industrial hygienist has not reached maturity if his major responsibility is to sort the gilt-edged low-risk operations for recommended coverage rather than to devise programs that will bring the hazardous operations under control. The industrial hygienist in educational work cannot hope to have a mature approach to his problems unless his contacts with industry have been sufficiently prolonged to enable him to formulate sound practical ideas. Industrial hygiene personnel, whether employed by Federal, State, or community health agencies, by industry, by insurance companies, or by educational institutions have a primary responsibility of protecting the health of working people. The official agencies, as well as insurance companies, are frequently more concerned with furnishing service to small industrial establishments and in promoting development of the field, while industrial personnel are employed chiefly by industries with ten thousand or more employees. Regardless of his affiliation the industrial hygienist must report factual findings to management and, if and when indicated, interpret them and their preventive aspects to the employees. He has an obligation to foster and promote good-will between employer and employees and to avoid at all times any offhand or ill-considered remarks that could endanger the good employer-employee relations that have been so greatly endangered in recent years by the influence of selfish motives and foreign ideologies. Wherever harmful exposures are found in industry or in the community, the industrial hygienist is obligated to present management with factual support of the need for control and to urge that practical controls be adopted. He should perhaps let management take the initiative and merely offer assistance when nuisance abatement or comfort are the goals at stake. Only when management definitely refuses to correct a proven hazardous condition should he consider using the "big stick."

PUBLIC health people rightly take the position that the physician's responsibility is in safeguarding the health and welfare of the public. We can have no conflict with that viewpoint, but, in our profession, we are obliged to consider also the economics of the situation. The profit motive in industry cannot be ignored for it is the basis of our way of life. If we want to become mature we are obligated to find, or help industry find, an economically feasible means of controlling any situation we condemn. In fact, the industrial hygienist is on a sound basis when he performs the service of showing industry how to apply science to any practical control of the environment regardless of whether the goal is health, safety, comfort or improved production. Every sound thinking loyal American is interested in improving the quantity and quality of materials produced by our country in order to improve living standards, lower costs and keep America strong. That is a fundamental necessity in preserving and improving the nation.

IN THE MAIN, industry is so hungry for factual guidance in the fields of health protection and safety that once the information is presented in a practical way it is absorbed and applied with amazing alacrity. I recall one occasion when a plant manager walked into my office with a roll of blueprints under his arm. He spread them out on the table and discussed ventilation and some special problems in waste disposal with our staff. When he was ready to leave he said, "I'm grateful to you fellows for taking the time to discuss these problems with me. I didn't know that this sort of information was available anywhere within the corporation." There are so many obvious reasons why healthful working conditions are good for management that the direct approach rarely fails. Successful management is eager to buy environmental improvements but is staunchly opposed to wasting money in pampering, feather bedding, boondoggling, or in relinquishing management's prerogatives of providing for the health and safety of its employees.

As an Association we should resist any attitude or practice in the guise of health and safety that imposes unwise restrictions or expenditures for controls, the need for which cannot be supported by facts and common sense. Environmental controls advocated solely on the grounds of unwarranted codes, practices, or whims with no factual support should be resisted by industrial hygienists. We must resist the writing of unsound codes and aid in their revision. For example, recirculation of air should not be barred where health hazards are not involved, otherwise heat losses in winter are unnecessary burdens. There is no reason why management should be required to spend more money than absolutely necessary to achieve health protection, nor does any good come from undue pressure to move with great rapidity unless the need is urgent. Whenever time or money is wasted, you and I share the expense because it all figures into the cost of production. Whenever we buy his products, we have to pay the producer costs plus a margin of profit calculated to keep him in business.

Frequently all that is necessary to implement an environmental improvement is to spur the imagination of management—make it easy to grasp a factual idea that can be applied and then be prepared to furnish advice and assistance once the idea takes root. However, since industrial hygiene is based upon a factual foundation and not upon an opinionated one, before we can expect to achieve corrective measures we must clearly demonstrate that there is something that really needs correction. The first step in making ourselves understood is in the choice of plain understandable language unobscured by technical terms and with a greater use of illustrations and demonstrations. There is no better truism than the old statement "One picture is worth a thousand words." Perhaps another truism we need to develop and implement to more advantage would be "One demonstration is worth a thousand pictures."

Getting an idea across to management is the all-important step and it isn't always easy. How often have you heard the remark, "Why is it that we have to kill somebody before we can get people to do something?" The "why" is simply that you and I have not been able to sell our wares. There may be many reasons for this but the outstanding one is that somehow management did not grasp the situation and did not understand the potential hazard involved. Where there is one situation involving risk of fatal consequences there are hundreds of situations involving possibilities of environmental improvements that, although their neglect would produce no clearcut ill health and much less a fatality, can materially enhance employee satisfaction and industrial relations as well as production. Solving a minor production problem by the application of controls for dust, noise, vapor or radiant heat may be a simple and easy way of gaining the confidence and respect of men in managerial positions who may need to know more about preserving man-power. We may recognize this possibility and have the courage of our convictions but be entirely unsuccessful in selling an idea to management. Unless we use care, we may not speak management's language. We talk in terms we understand, but usually in a tongue that is foreign, and sometimes even repulsive, to men in industry if they do not clearly understand what we are trying to say. A photograph of an installation similar to the one we are attempting to sell, or a

chart or drawing illustrating a point we want to make, serves as a universal language. *Demonstrations* of radiant heat and its control; explosive effects of dusts and vapors; the principles of process ventilation, and make-up air; and noise and its control have a universal appeal to any audience. When properly prepared they are the most convincing presentation one can possibly make. Although they are entertaining and educational to professional groups they are most productive when presented to industrial management groups or associations.

Management is not easy to approach on the basis of finding fault with what they are presently doing, but infinitely easier on the basis of presenting a way improvements could be made that would enable them to do even a better job than they are doing. Criticism of an employer's concern for the welfare of his employees is not the preferred method of winning support for environmental improvements, even when the criticism can be supported by facts. Results are more readily obtained by giving management a good reputation to live up to and spelling out what we want in terms that are completely understandable. Although the personnel director, the medical director and the safety director are important contacts whenever a plant visit is made, experience has shown that one of the surest and quickest ways of getting sound environmental improvements made is to enlist the interest and know-how of such people as architects, plant engineers, process engineers, master mechanics, foremen and other plant personnel. If you have an engineering package, a process change, a plant layout change or a change in building design you want to get accepted, someone will have to sell the idea to the man charged with that particular responsibility. The advantages to be gained from our association with these people and the opportunities for mutual education are obvious. Many an impractical control plan has blossomed into a sound practical installation by such an association. Also, where plant people participate in the planning, resistance to the actual installation fades.

INDUSTRIAL hygiene has unique tools and know-how but holds no unique position in its responsibility to society. Its existence is justified by its usefulness to working people, to industry, to the community and to the nation. *Teamwork*, the very foundation upon which our profession is built began with the physician, the chemist and the engineer, but must include along with other allied professions, the employees, the representatives of management, our communities and our country.

We may have reached maturity in our own understanding of a problem, but we have not even approached maturity in our ability to educate people in industry. We have recognized the futility of talking only to each other, but we have not made very encouraging progress in mastering the technique of serving up factual information in a palatable form to industrial management. The mere fact that, as a group, we have a know-how necessary to the maintenance of health and safety and the successful conduct of many industrial operations, does not relieve us of the responsibilities of education. In short, any individual wanting to be successful must produce something useful and then get out and sell the product.

DONALD E. CUMMINGS, whom we commemorate tonight, was such a man. While doing graduate work as a chemical engineer at Massachusetts Institute of Technology he developed tuberculosis and went to Saranac Lake for treatment. There he met DR. LEROY GARDNER who had also come to Saranac for treatment earlier and who later became director of the Saranac Laboratories. Their association is a typical example of teamwork to develop facts enabling industry to make enormous strides in effectively improving the health of employees. CUMMINGS applied this knowledge to the metal mining industry in several mid-western states including Missouri, Colorado, Wisconsin and Michigan. He conducted surveys to determine underground dust conditions in relation to mining methods and mine ventilation. He was instrumental in the development of medical control measures including chest x-rays of the miners for evaluation at Saranac. As a result of these studies many competent ventilation and dust control engineers were developed in the mines involved, with widespread effect in controlling silicosis and tuberculosis in the metal mining industry. CUMMINGS had the ability to inspire confidence and impart his knowl-

edge and ideas to others in such a way that they were eagerly received. In short, he was a good salesman.

THE AIHA QUARTERLY offers an excellent opportunity for sales efforts. Even though the *Quarterly* has made phenomenal progress from the time of its faltering start in 1946 we need to nurture it so that it can grow into a better educational medium than it is today. We should be, and we are, grateful to every one of the many people who have worked so hard to make it a success. People in many walks of life are beginning to learn through the *Quarterly* that industrial hygiene is not limited to personal hygiene, housekeeping, and sanitation, but encompasses a broad field of applied science with many practical answers to a host of environmental and community problems.

Education of the employee regarding health and safety is a most important part of any successful program and experience has shown that, although talks direct to groups of employees have some benefit, employee education and cooperation is best obtained through the foreman and the plant medical staff. Only through this route can the employee be properly and currently informed regarding the specific process or operation and the specific plan in force in the plant. Employees are not restricted to a passive role in health and safety. They can participate both through the suggestion route and the grievance route. If they have been properly informed of environmental facts pertaining to their work, they are not so likely to weaken their position by crying "wolf" unnecessarily.

AS INDUSTRIAL hygienists our special characteristic is diversity of professional training. Professional people in general are clannish. They delight in attending conferences or meetings where they can listen and talk to others in their own profession—people who talk and understand their language. This is a natural, desirable situation, but it fosters a narrowing point of view instead of a broader one. For instance, the acoustical engineers get together and discuss the highly technical phases of industrial noise problems and they delight in arguing the advantages and disadvantages of this or that technique in terms that are very confusing to the uninitiated. There may be agreement on only one point—that only an acoustics engineer is qualified to participate in the work and any real progress in the field can be anticipated only through the efforts of the profession. The chemist likewise has his own unique jargon and know-how and rather clear-cut ideas of how they are to be utilized. In fact, he may regard it as an unfriendly act if a non-chemist offers unsolicited advice in the matter. The physicist, a more recent member of the health maintenance team, has been understandably reluctant to share his know-how and bring the "cutie-pie" down from its pedestal and place it in the tool chest beside the midget impinger. The physician perhaps has the most complete and best safeguarded vocabulary of all the professions and his professional ties and interests have always been notably strong. It is not difficult to find individuals in the medical profession who believe that only a man with a degree in medicine is qualified to judge, or even express an opinion regarding the effects of any material on the human body or for that matter the symptoms exhibited by an animal on test. The absurdity of all these ideas of professional grandeur and monopoly is rather obvious and need not be discussed among enlightened people in the health maintenance field, but they do serve as warnings of what can happen to us if we allow selfish professional interests to prevail over our desire and ability to collaborate in the interests of doing a better job.

The outstanding asset of our group of professional people is our ability to cooperate and exchange ideas, each understanding and weighing the views of the other. The collaboration, though not entirely abolishing professional pride, has tended to remove ivory towers and subdue professional jealousies in the interests of getting the health maintenance job done expeditiously and correctly. We cannot endorse the bedside manner of the chemist or the mechanical engineer and the prudent non-medical industrial hygienist will scrupulously avoid diagnosis and treatment. The physician's or even the physicist's ability to supervise changes in a process, the ventilation of a plant or a plant layout cannot be regarded as infallible. Yet, when the views of all

professions concerned are considered in any planning that involves the health and safety of employees, the plan evolved from the several viewpoints is usually substantially improved over the one devised by one man or group of men representing only the profession primarily concerned.

In our search for the shortest distance between two points—that between an idea for environmental improvement and a successful plan or installation—we must never forget that industrial hygiene was founded on the concept of *collaboration* among the professions, all working together to improve the industrial environment. We must be careful to preserve this concept.

The Symposium on Instrumentation

THE Symposium on Instrumentation for Industrial Hygiene was held at the University of Michigan, Ann Arbor, Michigan, May 24-27, 1954. More than 600 persons registered for the meeting. Agencies cooperating with the University's Institute of Industrial Health and the School of Public Health in the presentation of the Symposium were the following: Air Pollution Committee, American Meteorological Society; American Conference of Governmental Industrial Hygienists; AMERICAN INDUSTRIAL HYGIENE ASSOCIATION; Bureau of Industrial Hygiene, Detroit Department of Health; Division of Occupational Health, Michigan Department of Health; Industrial Hygiene Foundation of America, Incorporated; Occupational Health Division, U.S.P.H.S.; Scientific Apparatus Makers' Association. Technical Sessions and lecture meetings were grouped as follows: Section 1—Sampling and Analyzing Air for Contaminants in Work Places; Section 2—Laboratory Type Instruments of Specific Application to Industrial Hygiene; Section 3—Instruments Specifically Designed for Atmospheric Pollution Evaluation; Section 4—Home-Assembled Instruments; Section 5—Instruments for Measuring Air Velocity and Metering Air; Section 6—Instruments for Measuring Sound Vibration; Section 7—Instruments for Measuring Ionizing Radiations; and Section 8—Instruments for Measuring Ultraviolet, Visible and Infra-Red Energy. Ninety participating manufacturers contributed generously to the success of the four-day meeting with their interesting and instructive exhibits. Especially well received was the display of home-assembled instruments. Some twenty-three national, state and private concerns showed more than 100 useful, and in many cases, ingenious, contrivances. An Encyclopedia on Instrumentation will be published from the material presented at the Symposium. This publication will be edited by a technical board of experts and will include the collected papers, together with descriptive information by the manufacturers of the instruments exhibited. It should prove to be a valuable reference for users of instruments.

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Research in Instrumentation for Prevention of Industrial Health Hazards

Catalytic Combustion

EVALUATION OF CATALYSTS

AMOS TURK, Ph.D.
Tarrywile Lake Road, Danbury, Connecticut

THE ADVENT of catalytic combustion* as a practical method of air purification has recently been described by several workers.[1-7] The physical forms of the catalysts include: (a) an element resembling a metallic air filter mat and consisting of a heat resistant alloy ribbon with a thin platinum alloy coating on its surface;[4-7] (b) a ceramic unit containing porcelain rods set between porcelain end plates, each rod coated with a mixture of platinum alloy and activated alumina;[2] and (c) pelleted or granular catalysts.[1,3] There has been very little information available, however, on evaluation of the performance of any given catalyst as a function of various process variables. A rigorous laboratory evaluation of any method of catalytic combustion should be conducted before any full-scale unit is installed, to determine optimal operating conditions.

This report describes equipment and methods for evaluating pelleted or granular combustion catalysts. Results of several specific tests are given. The equipment can easily be modified to facilitate its use for evaluation of the alloy ribbon or coated porcelain rod types of catalyst.

Catalyst Performance and Process Variables

THE FOLLOWING aspects of catalyst performance are important in determining catalyst selection and operation: (a) efficiency of combustion of contaminants; (b) efficiency of deodorization of the air stream; and (c) the rate of decrease of efficiency during service.

It should be recognized that combustion and deodorization efficiencies are not the same, for several reasons. First, odor intensity is a logarithmic, not linear, function of the concentration of odorous gases and vapors. When the odor intensity is decreased to its threshold value, however, odor removal is 100% efficient, even though combustion efficiency may not be. Further, where the reference point is at some location other than the point of emission, e.g., at ground level, dilution in outside air may be effective in increasing the deodorizing efficiency. Second, inefficient catalytic combustion does not necessarily imply that some contaminants are completely oxidized to odorless gases while others are not affected—it is more likely that a significant portion of the contaminants is only partly oxidized. Thus, for example, oxidation of aldehydes or ketones to organic acids may actually intensify the odor and make it more objectionable. Finally, the ultimate oxidation products of some substances (e.g., sulfur and nitrogen compounds) are not odorless. This latter effect may be minor, because the odor thresholds of sulfur dioxide and oxides of nitrogen are so much higher than that of organic sulfur and nitrogen compounds.

Process variables which are likely to play important roles in affecting catalyst performance include: (a) chemical composition of contaminants; (b) concentration of contaminants; (c) temperature of air stream entering catalyst; and (d) pattern and rate of air flow through catalyst bed.

Chemical composition of the contaminated air stream determines the oxidizability of the impurities by the catalyst used, the degree of deodorization effected by the oxidation, the presence or absence of catalyst-poisoning impurities, and the heat value per unit quantity of contaminant. The concentration of contaminants affects the mini-

*Also called "catalytic oxidation" or "catalytic incineration."

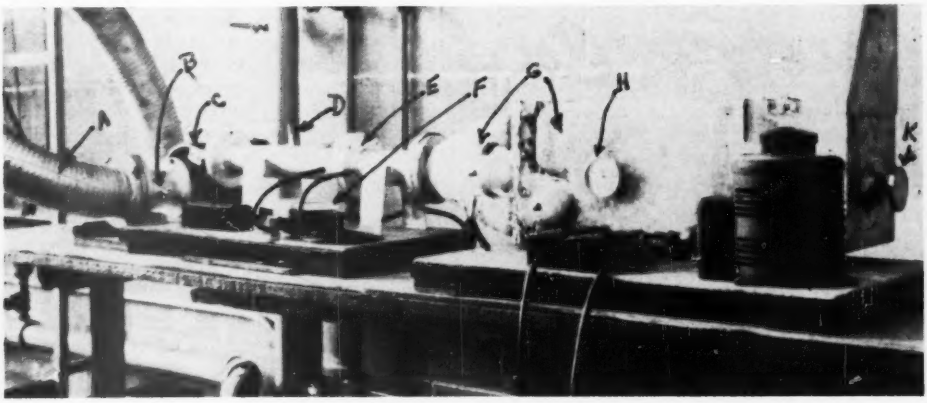

Fig. 1.
An apparatus designed to evaluate combustion catalyst performance as a function of process variables.

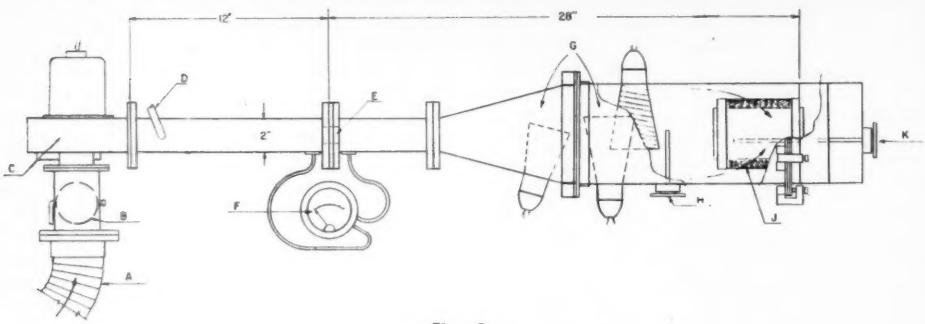

Fig. 2.
Plan for apparatus shown in Fig. 1.

mum entering temperature needed to initiate catalysis, the total heat production and hence the temperature of the exit gas, the temperature of the catalyst bed and the combustion efficiency. This important influence of inlet concentration on combustion efficiency has not been emphasized in the literature on this subject.

The entering air temperature also affects combustion efficiency and hence the quantity of heat produced. The rate of air flow through the catalyst determines its minimum area and depth required for any given efficiency. The air flow pattern should always be as uniform as possible to ensure uniform combustion efficiency.

Test Equipment

FIGS. 1 AND 2 illustrate apparatus designed to evaluate combustion catalyst performance as a function of the process variables discussed in the preceding section. The apparatus enables the investigator to duplicate actual stack conditions on an experimental scale, and to vary the conditions to study the range of catalytic effectiveness. A flexible metal hose (A) permits direct stack sampling where desired. The air stream is drawn by blower (C) and regulated by an adjustable damper (B). Tap (D) is available for checking odor or obtaining gas samples for analysis prior to combustion, or for introduction of additional contaminants where desired. It is generally useful to determine the gas composition at this point as "percent of lower explosive limit" (% L.E.L.). The total air velocity is measured by the pressure drop across the 0.875 in. diameter circular orifice (E). A magnetic actuated diaphragm gage (F. W.

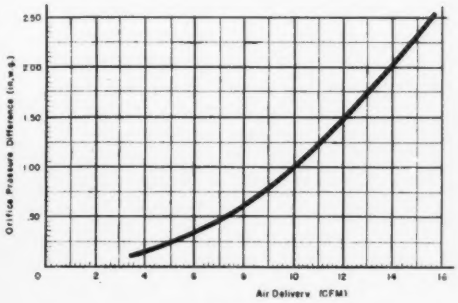

Fig. 3.
Air delivery of catalytic test unit (0.875" orifice in 1.88" I.D. steel tubing).

Dwyer Mfg. Co., Chicago) (F) serves conveniently as the manometer. Fig. 3 shows the air flow-pressure drop relationship for this orifice. The metered contaminated air then passes through space (G) which contains three 660 watt cone heating elements, one of which is regulated by a variable transformer. Dial thermometer (H) measures the temperature of the air stream before the catalyst. It is recognized that the thermometer readings are subject to some radiation errors.[8] An aluminum radiation shield, not shown in the diagram, was provided for thermometer (H), but the magnitude of the residual radiation error was not determined. In this way an air stream of fixed contamination, rate and temperature is passed through the catalyst bed.

The catalyst consists of a uniform bed of pelleted or granular material housed in a cylindrical canister (J). The canister[9] consists of an inner and outer perforated cylindrical shell, the annular space between which is filled with the catalyst. Catalyst bed depth is conveniently adjusted by varying the difference between the diameters of the two coaxial cylinders.

The canister used in the tests described in the ensuing sections provided a 0.7 in. bed thickness and 5.25 in. length. The total weight of the platinum-alumina catalyst contained in this canister was 1.32 lb. Average duration of contact of air stream with the catalyst bed may be calculated by:

$$\text{Duration of contact (sec.)} = \frac{60 \times \text{Vol. of catalyst bed (in.}^3\text{)}}{\text{gas flow rate (in.}^3\text{/min.)}}$$

The temperature of the exit air stream is measured by thermometer (K); the air is then vented or tested for odor or chemical composition. Fig. 4 shows the actual temperature losses sustained when uncontaminated air is blown through the unit. It may then be assumed that any gains in exit temperatures are caused by the heat values of oxidized contaminants.

Field Testing

THE EQUIPMENT described in the preceding section can readily be applied to field use. The temperature of the contaminated air stream should first be measured at the location where the full-scale catalytic equipment would most likely be installed. The air may then be sampled by connecting the inlet end of the flexible hose (A) to the stack at any convenient location where the contaminant composition is representative, and not necessarily at the point where the temperature was measured. The blower is then turned on and contaminated air is supplied to the catalyst at a rate determined by the damper (B) setting. The temperature of the air stream may then be adjusted to duplicate that in any part of the stack by suitable heat input before the catalyst. In this way the conditions which would be encountered in full-scale catalytic combustion application are fully and readily reproduced.

A field test was made at a wire enameling plant. The coating being baked in the pro-

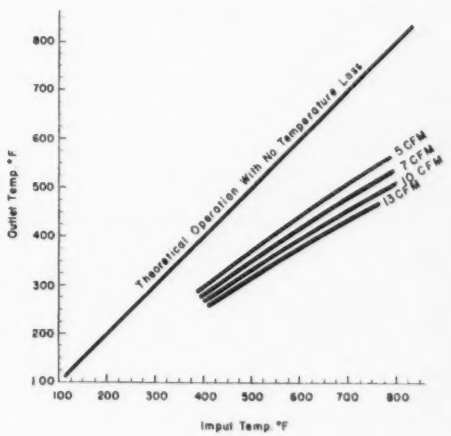

Fig. 4.
Temperature losses in catalytic test unit operating on pure air.

TABLE I.
CATALYTIC COMBUSTION TEST—WIRE ENAMEL OVEN

Catalyst	Air Flow		Equilibrium temperature, uncorr. °F.		Concentration % L.E.L.		Odor	
	Rate, cfm	Duration of Contact, Sec.	Before Catalyst	After Catalyst	Before Catalyst	After Catalyst	Before Catalyst	After Catalyst
Platinum—Alumina pellets, ⅛" (Note a)	7	0.21	610 (Note b)	710	4.5-5	0	Very strong phenol and aldehyde. Visible fumes	Very slight burnt. No visible fumes
	10	0.14	605 (Note b)	700	4.5-5	0	"	"
Fischer-Tropsch catalyst 108-B, ⅛" pellets (9)	7	0.21	620	585	3.5-4	0	"	Fairly strong phenol and aldehyde. No visible fumes.

(a) Baker & Co. Newark, N. J.
(b) Catalytic combustion started at initial temperature (uncorr.) of 560° F.

cess oven consisted of one-half Nylon and one-half Formvar.[7] The results presented in Table I show that the prevailing stack conditions permitted effective deodorization by catalytic combustion with platinum-alumina pellets provided the inlet temperature was at least 560° F. A Fischer-Tropsch catalyst 108-B[10] gave somewhat less effective results under conditions of lower inlet concentration of contaminants. These results indicate the type of field information obtainable by application of the test equipment. More extensive and prolonged tests to evaluate service life and other variables can readily be scheduled.

Laboratory Tests on Prepared Contaminants

THE EQUIPMENT described can also be used effectively for laboratory development of catalytic combustion of prepared contaminants. A suitable injection system to provide a contaminant stream of known rate and concentration is required. This is usually conveniently achieved by bubbling a metered air stream through two bottles of the contaminant liquid in series, both bottles being held in a constant temperature bath. The contaminant concentration may then be calculated directly from vapor pressure data,[11] assuming that the air stream has been saturated with the vapor. This assumption is valid if an efficient gas dispersing bubbler is used. Two containers in series are desirable because the second suffers only little evaporation and hence is usually close to the bath temperature. To avoid condensation effects, bubbler temperatures should be below the ambient temperature. The contaminated stream thus prepared may be conveniently mixed with a larger quantity of uncontaminated air, to make a pre-catalyst stream of desired concentration. CAUTION: the percent of the lower explosive limit (% L.E.L.) of the pre-catalyst stream should always be determined instrumentally and be in a safe range before external heat is applied.

The data of Table II show the results obtained in some laboratory tests of combustion contaminants. The following conclusions, drawn from these data, illustrate the type of information which can be obtained by the method, and are, incidentally, interesting in themselves.

1. Under the conditions used, practical deodorization of an air stream contaminated with 910 PPM of methyl ethyl ketone (5% L.E.L.) requires a minimum inlet temperature of 700° F (uncorr.), using platinum-alumina combustion catalyst pellets. (Runs 1-3)

2. As the concentration of methyl ethyl ketone is increased, the minimum necessary inlet temperature decreases. At inlet concentrations above about 20% L.E.L., the catalytic combustion is self-sustaining even after heat input is eliminated. (Runs 4-9)

3. The intermediate combustion products of methyl ethyl ketone include formaldehyde and acetic acid. (Runs 5, 12)

4. The catalytic combustion method using platinum-alumina pellets is effective for deodorizing toluene and naphtha. (Runs 16-18)

5. Under the conditions described, isopropyl alcohol is more difficult to oxidize than the other contaminants tested. (Run 15)

TABLE II.
LABORATORY TESTS OF CATALYTIC COMBUSTION

	Air Stream Before Catalysis							Air Stream After Catalysis			
Run	Contaminant	Concentration PPM (Vol.)	Concentration %L.E.L.	Flow rate (cfm)	Temp. °F.	Odor	Catalyst	Conc. (%L.E.L.)	Temp. °F.	Odor	Catalysis Sustained With no Heat Input?
1	Methyl Eythl Ketone	910	5	7.2	500	M.E.K. (Moderate)	Pt-Al_2O_3 Pellets	2.5	400	M.E.K. (weak)	No
2	"	"	"	"	600	"	"	<1	490	M.E.K. (faint)	"
3	"	"	"	"	700	"	"	<1	590	M.E.K. (barely detectable)	"
4	"	1250	7	4.2	700	"	"	<1	640	none	"
5	"	2200	12	7.2	500	M.E.K. (strong)	"	1	585	M.E.K. & acetic acid (faint)	"
6	"	"	"	"	600	"	"	0	625	none	"
7	"	3600	20	"	500	"	"	0	700	none	"
8	"	3800	21	"	500	"	"	0	800	none	Almost, falls off very slowly
9	"	6850	38	"	500	"	"	0	1000	none	yes
10	"	3800	21	"	530	"	Fischer Tropsch (9)	0	860	none	no
11	"	"	"	"	600	"	"	0	910	none	Almost, falls off very slowly
12	"	"	"	"	660	"	Cr_2O_3-Al_2O_3 Pellets	0	950	Formaldehyde	no
13	Methyl Ethyl Ketone & Cresol	1800	10	"	700	M.E.K. & Strong Cresol	Pt-Al_2O_3 Pellets	0	1000	none	no
14	Methyl Ethyl Ketone & Butyric Acid	1800	10	7.2	700	M.E.K. & Strong butyric acid	Pt-Al_2O_3 Pellets	0	1000	none	no
15	Iso-Propyl Alcohol	2000	10	"	620	Strong alcohol	"	0	580	alcohol	"
16	Naphtha	800	10	"	630	Strong naphtha	"	0	600	none	"
17	Toluene & Cresol & Butyric Acid	1400	10	"	600	Strong toluene & cresol & Butyric acid	"	0	670	none	Almost, falls off gradually
18	Toluene	3900	28	"	600	Strong toluene	"	0	800	none	yes

6. Impurities in relatively minor concentrations but with highly objectionable odors may be deodorized by being oxidized together with the major combustible contaminant (e.g., cresol, butyric acid). (Runs 13, 14, 17)

7. When conditions of temperature and concentration are favorable for catalytic combustion, less active catalysts (such as metallic oxides) may be sufficiently effective. These may be less expensive and less readily subject to poisoning than the noble metal catalysts. (Runs 10-12)

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MEDICAL RESEARCH PROGRAM IN INDUSTRY

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Standard Oil Development Company, Linden, New Jersey

THERE EXIST numerous problems of medicine in industry which need further research effort. For instance, how can the cardiac be used in industry, effectively, yet safely? What is the effect of noise on employees, and how should this be handled? What are the effects of air pollution on health and well-being? These are but some of the medical problems of industry which need research for their solution.

Our own interest in organized medical research began about 1945, when several of the executives of our company began to wonder what the effects of the increasing use of additives in petroleum products might have upon the users of those products. Prior to that time, ROY BONSIB had reviewed potential toxicity hazards and written recommendations for their control based principally on literature searches.

In order to insure that the Division would obtain the proper perspective, company-wide, on potential toxic hazards, a Toxicity Subcommittee was created (Fig. 1).

To this committee our Division serves as advisor. Potential problems are referred to the committee by the various groups represented, or by any other person or group within the company. From these groups the Medical Research Division is familiarized with the contemplated use of the compound under consideration, the volume of business contemplated and other technical facts which will put the potential problem in its proper perspective. New uses for old products can be reviewed from a toxicological standpoint during or before this use.

Perhaps one of the most dramatic cases of the effect of additives is the well known example of tetraethyl lead. In its developmental stages, it was found that this compound had serious effects upon the health of workers. Naturally, therefore, the question immediately arose whether or not in the amounts present in gasoline it would have an effect on the health of gas station attendants, automobile mechanics, automobile operators, and, from breathing the lead in automobile exhaust, on the general public. As a result of a brilliant piece of research by DR. ROBERT KEHOE and his associates, the answers to these questions were obtained and we all today use tetraethyl lead without worry. This does not make it any less toxic today than it was in 1920.

The Division had its origins in one individual who served as advisor to this committee. As the number and scope of the problems referred to this individual increased, additional personnel have been added, until today the organizational set-up of the Division is as indicated in Fig. 2.

Once a problem has been referred to the Toxicity Subcommittee, the Medical Research Division begins to accumulate the information which will make it possible to evaluate any potential health hazards which may be associated with this use. Our first source of information, naturally, is the literature, to determine whether there is any published toxicological work. If we are unable to find the required information in the literature, we next turn to others who may have sources of information not available to us or in the literature. These are our

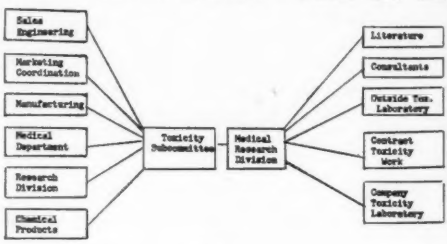

Fig. 1.

Presented at the Sixth Annual Health Conference, Houston, Texas, October 1, 1953.

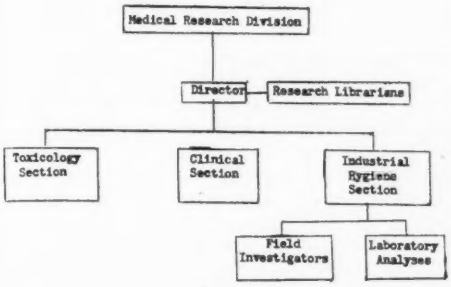

Fig. 2.

friends and acquaintances in other industries, the universities, or government who may be able to furnish us the desired information. Finally we consult other toxicity laboratories, in industry or elsewhere, who may be able to provide us the toxicity information we need.

As a result of this preliminary ground work, we are able to evaluate what is known, and what additional information will be needed, and plan the toxicity studies which are indicated. These studies may be done in our own laboratories if the facilities are available, but if not, then they are performed under contract by one or another toxicity laboratory. It is very important that the toxicity laboratory chosen be well versed in toxicological techniques, otherwise completely extraneous, misleading, or irrelevant results may be obtained. The simple fact that a compound may or may not be toxic, by itself is of very little help in attempting to evaluate the hazards from its use. This was illustrated by the case of tetraethyl lead, the toxicity of which was not altered by DR. KEHOE'S work but the hazards of handling were definitely eliminated by his work. In addition it is essential to know where it is to be used, how it will come in contact with people, how often and for how long contact will continue, etc.

Once the toxicity information has been developed, either from the literature or from actual toxicity laboratory investigations and it appears that a material may present a potential health problem, then the Industrial Hygiene Section takes over and studies the possible exposures and methods of controlling them. Is the exposure from breathing the material, from contact with the skin, or from ingestion, or from a combination of these? How often does exposure occur? How long does each exposure last? What level of exposure occurs? What are the work habits of the men and how can they be altered so as to minimize exposure? What are the engineering features of the equipment and how can they be altered or ventilation improved to reduce exposure? Can non-toxic chemicals be substituted for toxic ones and still accomplish the same operating effect? Will protective equipment provide the necessary protection where exposure cannot otherwise be avoided, and if so, what protective equipment should be provided and where and how should it be used? This is the type of question which can be answered by the Industrial Hygiene Section after careful study, collection of samples where indicated, and analysis of samples after collection. Let it be emphasized at this point that the techniques of industrial hygiene are not unique in and of themselves, but frequently the collecting methods are quite specific, and the amounts of material being analyzed are quite small, so that special analytical techniques must be used. Therefore, it is essential that the industrial hygienist be fully familiar with the limitations and pitfalls of his techniques. This implies that he must have special training or long periods of supervised instruction in these techniques before he can be considered competent to interpret the significance of his findings. It often occurs that a safety supervisor is suddenly made responsible for industrial hygiene without any period of special training or previous experience. This is unfair to the safety supervisor, and in most cases would lead to a false sense of security. These remarks are not intended in any way as a criticism of safety supervisors, who have done an extremely wonderful job in a field in which the training and background must necessarily be different from those of the industrial hygienist. It is intended only to caution against expecting from the safety department personnel a service which they are not trained to provide.

When the Industrial Hygiene Section has completed its studies and developed the facts about exposure, then the Clinical Section swings into action. From the facts developed by the toxicologist and the industrial hygienist, an attempt is made to evaluate the

potential effects on man of exposures at levels determined by the industrial hygienists to compounds of the toxicity determined by the toxicologist. Will men be affected by these exposures? If so, how can the effect be measured? Are preplacement examinations necessary to exclude those who may be unusually susceptible? Are periodic examinations necessary, and if so, how frequently should they be done and what should the examination consist of? Should men be removed from the job if certain changes are observed and at what stage should they be removed? Are the controls recommended by the industrial hygienist adequate, or are more elaborate controls necessary? If an accident occurs, what is the best method of treatment, are there any antidotes, what first aid measures should be developed? These are the questions that must be answered by the Clinical Section. All of these answers should be available before any new process or the use of any new chemical progresses beyond the pilot plant stage. It has been found that if we develop this information for the protection of our own employees, then we are in a position to answer the questions which will be raised by the consumers of our products, and to assist them in the proper handling of our products without danger to their own employees.

In addition to evaluating the hazards from the use of new chemicals or new processes, our Division is also concerned with the development of new concepts in each of our three lines of endeavor. As an example, the Industrial Hygiene Section is performing research on new methods of sampling, new analytical methods, and improvement of older methods. Recently an extensive study of skin contact was undertaken in conjunction with the Medical Department of the Esso Standard Oil Company. The techniques developed were somewhat unusual and should be applicable not only within our own industry, but also in other industries with skin contact problems. A study of protective clothing is also under way to try to develop a suit which would provide protection, yet be cool enough that it could be worn in hot climates.

Our Toxicology Section is embarking now on a program of fundamental research on the effect of hydrocarbons on various metabolic processes. Are body enzyme systems affected by aliphatic or aromatic hydrocarbons, and if so, how? Do these changes in body enzymes occur before the body cells are visibly damaged? If so, do these methods lend themselves to application by the physician in studying the effects of different exposures before irreparable damage has been done? It is a fact that parathion is a very toxic material which will cause convulsions in men overexposed to it. However, long before convulsions appear, it will depress the blood cholinesterase. As a result, a practical field test has been developed to detect parathion exposures at a time when the only detectable change is in the blood cholinesterase. At this stage the blood cholinesterase will restore itself to normal, without having subjected the exposed person to any danger from convulsions. Are similar sensitive enzyme reactions occurring in benzene and other aromatic hydrocarbon exposures? Today our only measure of benzene toxicity is its effect on the bone marrow. When this occurs, irreparable damage has often already been done.

Because industry is always developing new processes or new products, or finding new uses for old products, we find that we are never lacking in work projects to be performed. We have found it advantageous to be set up organizationally in the Standard Oil Development Company, the central research affiliate of the Standard Oil Company (N.J.). This permits us to learn of new ideas as they are developed, and to work right along with the chemists and engineers as their efforts proceed from mental processes to laboratory bench work, to small pilot plant, to large pilot plant, to engineering design for full scale production units. Our efforts quite naturally vary with each stage of development, but our ultimate objectives are to identify medical or health problems arising from the manufacture or use of various petroleum and chemical products as they affect employees, customers, or the general public, and to investigate steps to be taken to minimize or eliminate such problems. Our motto is that no chemical is too toxic to be used, provided it is understood how to use it safely. Our program is designed to develop information essential to a proper understanding of the necessary precautions for the safe handling from a health standpoint of any chemical or process.

NOISE, NOXIOUS OR NICE

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AS ONE of the Nation's largest industrial employers and as a fighting organization, the Navy is directly concerned with the noise problem and its impact on the health, efficiency, and morale of naval personnel.

That noise is a factor of the first magnitude in the lives and well being of the human race is borne out by a mass of evidence. Noise may have a salutary or a detrimental effect, and what is music to some is noise to others. It is interesting to consider that if animals were not equipped with organs of hearing there would be no such thing as sound or noise; the pleasures and benefits of hearing and oral communication would not exist, and noxious noises would not be a nuisance.

As examples of nice noises might be mentioned the whistle of a steam locomotive, the wind in the tree tops, a babbling brook, the nightingale's note, the Barcarole and the voice of a Southern lady—a Texas lady if you please. As examples of some of the simpler noxious noises a list could be recited ranging all the way from a dripping faucet, on through the wail of a hyena, the raucous insistence of an automobile horn, and boogy-woogy music, down to reveille—to a Marine.

Noise as an entity of genuine import came to be recognized shortly after the beginning of what may be referred to as our industrial revolution and its significance, its perniciousness and its challenges have increased concomitantly and commensurately with the advance of science and industry.

Some of the new sounds are merely annoying; others may have an influence on psychomotor behavior; some reduce production or efficiency in activities where speech communication is important; and a few of the louder ones impair auditory acuity and cause physical damage or even permanent deafness.

Noise is now significant, because it exacts a substantial though difficult-to-measure toll on the morale and nervous energy of people everywhere; because employee workmen's compensation claims arising from hearing impairment can be exceedingly expensive; because effective speech communication must be maintained to assure production and fighting efficiency; and because we must conserve our limited industrial and military manpower and womanpower.

One is naturally reluctant to subscribe to what has been called the "devil theory" of noise which postulates that noise is ruining the public health, is filling our mental institutions, and has caused a decline in the birth rate! This theory assumes too low an estimate of human adaptability, and tends to render the whole problem insuperable unless we return, as we certainly are not going to do, to a medieval economy.

It devolves upon us to try to understand what the real effects of noise are, and try to reduce noise where that is economically and technically feasible, or to protect personnel from noise in all practicable ways where creation of the noise itself is unavoidable and necessary.

Perhaps the least harmful noises are those which are merely annoying, and this is the phase we can control most easily. The annoying character of a noise is not necessarily associated with its measured loudness. The factors which make a noise an annoyance, according to recent research are (1) interference with hearing what one wants to hear; (2) unexpectedness; (3) inappropriateness, as the cracking of peanut shells at a symphony concert; (4) intermittency, such as a dripping faucet; (5) reverberation; (6) intensity or loud-

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ness, and (7) the frequency pattern, the higher pitches being more annoying. Of course if the intensity is great enough, noise may become a more serious matter, a factor in causing deafness. The tolerance level for physical damage to the ear which is, in the long run, hard to measure, is possibly 100 decibels; but the annoyance tolerance level should be much lower. In any case it takes more than decibels to measure annoyance.

We should note that the absence of noise may be as distracting or as inimical to peace of mind and well being as is noise. The thunder of silence is something more than a figure of speech.

Noise as an entity has, during recent years, come to receive an increasing amount of attention and consideration. A national popular magazine has recently devoted a long article to noise. Some cities have begun to regulate horn blowing. There is certainly far more of it in America than say in London where a taxi driver weaves his way through disorderly traffic with very little or no use of his raucous horn. Some cities have induced private air lines to try to reduce noise which disturbs residential communities. In New York, managers of the Idlewild and La Guardia airports have encouraged residents to complain of disturbing airplane motors, as one step toward control. It was found that many complaints came in the afternoon. When the housewives had turned off their garbage disposals, mixers, and vacuum cleaners, and sat down to watch TV, they called the complaint department to protest the noise from airplanes. The problem of cutting down noise from planes landing at, or taking off from, airports, to avoid serious interference with musical concerts, or sleep, for example, is not easy. Changing of routes has helped in some instances, but you cannot tiptoe in and out of a city with a four-motored Strato Cruiser.

While it is generally accepted that noise impairs one's ability to accomplish work, tests seem to indicate that, owing to the worker's becoming used to it and his motivation to achieve in spite of it, psychomotor activity is not, in the long run at least, hampered by noise up to 115 decibels.

However, subjectively, all workers seem to prefer quiet rather than continuous noise. Intellectual work is done better in quiet circumstances, and executive offices are almost always in the quietest part of a plant or office building. City editors do seem to operate efficiently in a state of noise, but over a number of years, even in this case, the effect of noise on the nervous, if not the physical, system may be adverse.

Tests in connection with battle gunnery show that the surrounding noise does not impair the efficiency of gun crews assigned to the loading and aiming of artillery, but in practice stimulates the sharpness of the personnel engaged. This scientifically observed fact is fortunate since it is quite unlikely that there will be an opportunity to load and aim guns in quiet circumstances.

Most tests relative to psychomotor activity have been largely confined to situations where noise intensity is less than 115 decibels; and the effects of the higher intensities which we find on aircraft carriers cannot be predicted from these tests. The tolerance limit must be determined by further research. We are not likely to hear routinely, noises twenty or thirty decibels greater in intensity than those heard in World War II; but the number of mechanical contraptions emitting noises of a more traditional intensity has increased enormously.

Noise adversely affects production and efficiency where output depends in some way on speech communication, on the individual's hearing orders or information that he is supposed to hear. Interference with communication begins before a noise is intense enough to be hazardous in any other way. It creates misunderstanding which affects efficiency and may affect safety. Extra effort required as a result of misunderstanding, uses up nervous energy and thus reduces production, although the amount is hard to measure objectively. Very loud noise aboard aircraft carriers launching planes interferes with communication to such an extent that our experts have suggested that personnel in key command posts be taught lip reading.

It is estimated that the top communication level of noise is 85-90 decibels. Above that level, as at that stage of a cocktail party where there are more talkers than listeners, the masking effect of surrounding noise makes speech unintelligible.

The noise generated in the machinery spaces of naval vessels creates a formidable problem in attaining effective communication to and from these spaces. In the Armed Forces aboard aircraft carriers, in submarines, plane cockpits, and in diving operations, noise interferes with ability to communicate by voice and even by electrical inter-communication systems. In this connection the Navy has conducted research to determine what words can be understood most easily in plane-to-ground communication and similar circumstances. This in a real measure accounts for the seemingly trite jargon that constitutes the language of airmen and control tower operators.

Kryter says that the disrupting or masking of speech communication by noise can often be dealt with by elimination of the noise (sound proofing, isolation of machinery, etc.), especially in industry. He describes use of the "articulation index" which would enable the acoustics engineer to calculate in advance the effect that a particular noise will have on the ability of man to communicate by speech. The effect of noise on speech intelligibility depends on the spectrum of the noise, that is, on what *kind* of noise it is, as well as on its *intensity*. The articulation index is calculated from these two aspects of noise. This is a major technical and theoretical advance of the last decade. It enables engineers to meet specifications laid down in terms of possibility of communication, at least to the degree management is willing to pay the cost. It is an advance over the concept of specifications in terms of overall noise levels.

Personnel can be protected by ear wardens (plugs or obturators) against noise up to at least 90-100 db. (perhaps more) which interferes with communication. In noises with effective masking of more than 60 db. the wearing of ear plugs actually improves the reception of speech. This is true in the presence of continuous high-level noise but not when the voice signal occurs during an interval of reduced noise. The insertion of ear plugs reduces the noise reaching the ear as much as it reduces the speech signal, so that the signal-to-noise ratio remains constant. The over-all reduction of noise and the speech level presents a more moderate intensity of sound to the middle ear with a concomitant reduction of distortion. The situation is perhaps analogous to the improvement of vision when the glare of extremely bright light is reduced. In any noise whose effective masking of speech is more than 60 db., ear plugs will not interfere with speech reception. By "effective masking" is meant the number of decibels the noise elevates the threshold for speech. Whether ear obturators will be effective in facilitating speech reception where surrounding noise is 125 db. or more may be questionable. Above that level speech becomes less intelligible apparently because of its painfulness and/or overloading of the ear.

In the Navy noises of 100 db. or more are regarded as likely to cause impairment of hearing, temporarily or permanently, if the personnel are subjected to them over relatively long periods. The exact tolerance limits will require more extensively controlled experiments in industry and in the Armed Forces than we have had so far. Some individuals appear to be more sensitive to noise than others, and there may be significant differences in sensitivity as between older and younger persons. To reduce costs and avoid waste of manpower we may have to devise tests to select the least sensitive individuals to work in the noisiest environments.

As the art of war has advanced we have created new and more difficult noise problems. Sound levels as high as 150 db. have been measured near the exhaust of a turbojet aircraft engine, a level which will require improved instruments to measure accurately. Inside the cockpit of the turbo-jet plane the level is about 115 db. There is no longer any doubt that noise intensities of 120 db. or more, impair man's hearing, at least temporarily.

In the early days of jet aviation, fears were expressed concerning the possible effects on man of the frequency characteristic of noise in the ultra-sonic range (sound barrier, etc.). Careful research has now shown that man is less likely to suffer from these high frequencies than from high intensity (120 db. plus) in the sonic frequency range.

There appears to be a lack of conclusive evidence concerning the non-auditory effects of noise; however, reliable investigators have reported the following effects of en-

gine noise of an intensity of 150 db. and a frequency of 700-1500 cycles per second: (1) severe but temporary hearing loss, (2) heating of the skin, (3) blurring of vision, apparently from eyeball vibration, (4) sense of vibration of the cranial bones and air movement in the nasal passages and sinuses, (5) an apparent weakening of the body supporting musculature. Long exposure would undoubtedly cause deafness. Noise from bombs, guns, cannons, and in submarines and tanks also has effects of a serious nature, some of which are undoubtedly met with also in industry. The personnel who man the flight decks when afterburner jets are flown from carrier decks are probably subjected to the most rigorous continuous exposure to noise yet experienced by man. Their hearing acuity is likely to be seriously affected.

The conventional means of dealing with the problem of very high intensity noise are inadequate. The Committee on Hearing of the National Research Council recommended that the Navy appoint a small group to gather information regarding work in progress on the subject of acoustic trauma and the status of present knowledge on it; and to suggest the next steps to be taken in relation to the urgent practical problems arising from high-intensity noise. The group is to cooperate with the Air Force and industry.

A research contract was consummated by the Office of Naval Research with the Psycho-Acoustic Laboratory at Harvard University. This Laboratory became the base of operations for the so-called Noise Survey Team. The stated purpose of the Team was (1) to survey the state of research in the field of acoustic trauma due to high-intensity noise emanating from military weapons and vehicles, and (2) to formulate plans for research and development directed towards the alleviation of acoustic stress and the protection of personnel. Walter A. Rosenblith, of the Massachusetts Institute of Technology; Dr. Douglas E. Wheeler, field representative of the Subcommittee on Noise in Industry, American Academy of Ophthalmology and Otolaryngology, with the Navy's Commander Harold Smedal as Liaison Officer, constituted the team. Visits were made to aircraft carriers, individual scientists interested in the subject, concerns in the aircraft industry, and Air Force installations, and a report was made to the National Research Council in November 1952.

The Team studied the auditory acuity of personnel who were exposed to high noise levels for long hours. The data showed that most flight personnel suffered from severe hearing losses in the range above 1,000 cps.

During launchings, aircraft produced intensities that regularly reached 130 to 150 db. for reciprocating engines and low-powered jet engines. The use of afterburners and larger jet engines, turboprop engines, etc., which create noise of 160 db. or more, will make the noise problem more severe. As many as thirty men are involved at one time in the catapulting of jet-type aircraft, and the necessity for protecting the hearing of these trained crewmen is therefore an exceedingly important matter. Surprisingly enough, however, carrier personnel seldom complain of excessive noise.

During the next three to five years a sizable number of men will have to perform military tasks in noise levels above 140 db. and probably as high as 160 db. There is little hope that engineering developments will, during that period, reduce this acoustic stress. Both officers and enlisted men must be taught to wear the best ear protection that is currently available. The protection must be fitted to the individual ear with the advice of a physician. Ear canals differ considerably in cross-sectional area and in the direction and tortuosity of their course leading to the tympanic cavity. There are three Air Force installations where an effective program for ear protection is in existence. Properly fitted ear plugs are said to attenuate surrounding noise by as much as 30 db. for lower frequencies and 40 db. for the higher ones.

The limits of tolerance to noise pressure are not uniform over the audible frequency range, being lower for high-frequency-centered noise than for low-frequency-centered noise. There is some evidence that noise levels ranging to in excess of 100 db. do not cause any significant hearing loss where the noise is concentrated in the low frequencies.

The problem of noise from jet planes with afterburners transcends the auditory sphere. There are numerous indications of

non-auditory effects. It was recommended that a team representing the disciplines of psychiatry, physiology, acoustics, psychology, hormonal biochemistry, and medicine, make detailed proposals for future research in this field. This group was to initiate a "quickie" program at a location where high level noises could be synthetically produced or be produced by actual jets with afterburners. These scientists were to be familiar with carrier operations; and their areas of familiarity were to include auditory, visual, proprioceptive and vestibular phenomena, motor skills, human efficiency, the effects of vibration on hearing, and the autonomic and hormonal effects of stress.

Early this year the National Research Council formed the Armed Forces Committee on Hearing and Bio-Acoustics. A working group of experts under this Committee met at the Wright Air Development Center in Dayton, Ohio, in July to initiate the "quickie" program; and later new observations were made aboard an aircraft carrier. It was concluded that the redesign of carriers, in feasible ways from the operational viewpoint, could reduce danger from noise to about 500 personnel not on the exposed islands of the flight deck; but that redesign was impractical to protect the approximately 30 men whose duties compel them to occupy exposed positions.

The results of the new research program cannot be anticipated but at this stage it should be noted that reliable observers have reported the following non-auditory effects in the presence of high intensity noise: (1) apparent weakening of the body-supporting musculature, due perhaps to interference with normal proprioception; (2) vestibular upsets; (3) vibration of cranial bones and body cavities; (4) blurred vision caused by vibration of the eyeballs, a circumstance that might prove serious if visual communication is to be carried on; (5) increased adreno-cortical activity; (6) certain psychological effects ranging from poor performance on so-called vigilance tasks to acute feelings of anxiety and desire to escape from the noisy environment; and (7) increased fatigue and irritability. While not all of these effects have been measured under properly controlled conditions, they constitute valuable hypotheses for testing and experimental purposes.

While mainly concerned with the noise-man problem in flight decks, the Navy is also concerned with the noise around naval air stations plus the consequent public relations problem, and with the problem of those who work in and about engine test cells. Testing cells for both the older type of airplane motors and for jet engines have been installed at some if not all of the Navy's air stations. The principle involved in the construction of these cells is one that deflects the noise upward through a chimney-like arrangement, thereby reducing what was formerly a monotonous and deafening roar to little more than a purr.

Present knowledge does not permit a quantitative definition of the effects of various intensities and types of noise on hearing, in the sense comparable to the maximum allowable concentration values for certain chemical substances. The laboratory and field data presently available are valuable, but they must be supplemented by extensive controlled studies in the field before standards can properly be set up.

Alcoholism Studies

AN INSTITUTE on Alcoholism for registered professional nurses will be held at Yale University from July 29 through July 31, 1954. The sessions are being planned to acquaint a limited number of nurses with the nature and extent of alcoholism and with theories concerning the etiology of addiction. A particular emphasis will be given to the role of the nurse in interpreting to patients or to their families the nature of alcoholism and the necessity of securing specialized assistance following hospital treatment for acute intoxication. The course will consist of lectures and discussion sessions with a staff drawn from the faculties of Yale University and other institutions. This Institute is sponsored by the Yale University School of Nursing, the Summer School of Alcohol Studies, and the Connecticut League for Nursing. Inquiries should be addressed to: Yale Center of Alcohol Studies, 52 Hillhouse Avenue, Yale Station, New Haven, Connecticut.

Exhaust Rates for Dust Control

Theoretical Requirements in Bulk Material Handling Systems

W. C. L. HEMEON, Engineering Director
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IT IS WELL KNOWN to those concerned with the design of dust control systems that the required rate of exhaust from an enclosure, especially in bulk materials handling systems, is often dependent upon the rate at which air (air entrained by the falling motion of the individual particles comprising the material) is pumped into the enclosure.

Hatch[1] drew attention to the importance of the fact that each individual particle moving through air tends to drag a parcel of air with it. Dunlop[2] commented significantly on the importance of this phenomenon in the design of dust exhaust systems in the crushing and handling of gold ore. Pring[3] described some quantitative measurements of the magnitude of air flow induced by the fall of crushed material into a surge bin and in a later paper,[4] with Knudsen and Dennis, reported on the results of some laboratory studies on the magnitude of the air motion induced by a rain of water droplets.

In connection with the preparation of a volume[5] on the principles of industrial ventilation, the writer undertook to examine the nature of the phenomenon and to analyze the energy relationships involved. This led to the concepts set forth in the present paper.

Presented at the Fifteenth Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION, Chicago, April 29, 1954.

Air Drag

A PARTICLE in motion is subject to the resisting force due to air drag, the magnitude of which has been thoroughly explored and is a well established section of engineering information.[6] A knowledge of the particle velocity permits calculation of the resisting force which in turn permits one to compute the power represented thereby, and from a knowledge of the total number of particles in a stream, the total power. Such a system may be likened to that of an air moving fan (Figs. 1 and 2).

If we assume that all of the power is devoted to the acceleration of portions of the surrounding atmosphere to a velocity which can be inferred by the dimensions of a particular system (Fig. 3), a basis is provided for describing the theoretical maximum rate of air motion. In industrial ventilation the following expression is routinely employed to describe the relationship between air flow, resistance and horsepower:

$$\text{H.P.} = \frac{qh}{6360}$$

where the constant in the denominator includes the factor 33,000 ft./lbs. per minute and a factor for transformation of pressure units from pounds per square foot to inches of water column.

Consider now a continuous stream of falling particles (Fig. 3) whose trajectories taken in the aggregate are demarcated by

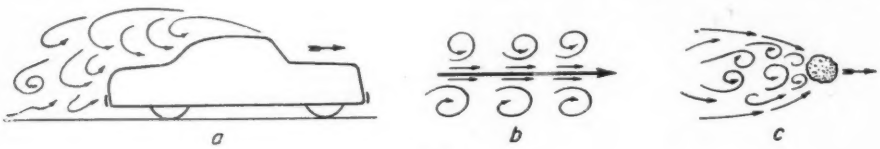

Fig. 1.
The turbulent air currents behind any moving body have a net forward component.

Nomenclature

F_r = force due to air resistance, lbs.
ρ = density of air, = 0.075 lbs./cu. ft. at 70° F.
Z = specific gravity of particle
u = particle velocity, ft./sec.
u_{500} = particle velocity, ft./sec. corresponding to R_e = 500, end of intermediate motion
a = cross-sectional area of particle, sq. ft. = $\frac{\pi D^2}{4}$
D = particle diameter, feet
d_m = particle diameter, microns, = 3.05 x 10^5 D
g = acceleration due to gravity, 32.2
S = distance traveled by particle
S_{500} = distance traveled by particle where velocity such as to result in R_e = 500, i.e., start of turbulent motion
q = induced air flow, $ft.^3$/min.
h_v = air velocity head, inches water
A = cross-sectional area of stream, $ft.^2$
P = power induced
N = total weight in column, lbs.
R = solids falling rate, lbs./sec.

a definite cross-section flow area, A. This area may be defined by the pathways of the outermost particles in an unenclosed stream, or by the walls of an enclosing chute. Let v represent the average velocity of induced air in any selected plane area. The corresponding velocity head will be

$$h_v = \left(\frac{v}{4005} \right)^2$$

which, when substituted in the power equation, gives:

$$H.P. = \frac{q}{6360} \left(\frac{v}{4005} \right)^2$$

When for v we substitute the equivalent q/A and rearrange the terms, the following expression results:

$$q^3 = (H.P.)\ A^2 \cdot 10^{11}$$

If one could estimate the value of power (H.P.) in any instance, this relationship would provide a basis for estimating a magnitude of induced air flow which cannot be exceeded. As will be pointed out later, the simplifying assumptions implicit in this development indicate that in practice the value must often be much less than this.

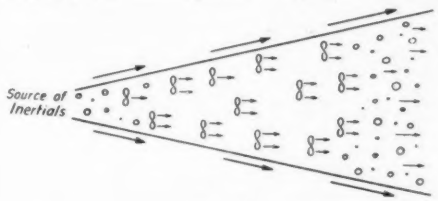

Fig. 2.
Each separated individual in a stream of moving particles contributes to forward air motion. The system might be likened to myriads of miniature fans.

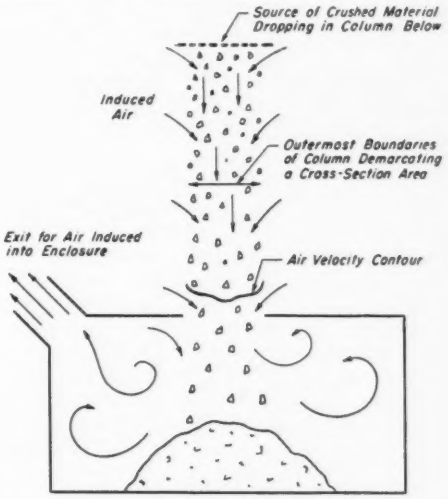
Source of Crushed Material Dropping in Column Below
Induced Air
Outermost Boundaries of Column Demarcating a Cross-Section Area
Exit for Air Induced into Enclosure
Air Velocity Contour

Fig. 3.
A stream of crushed material falling into a bin, illustrating dimensions of air induction.

Power Generated by Falling Particles

THE DIFFERENTIAL power dP generated by a particle in motion is:

$$dP = F_r du$$

where F_r is the magnitude of air drag and du is the differential change in velocity (Fig. 4). The value of F_r must be represented by three different expressions according to whether the motion is turbulent, streamline, or intermediate. In the present paper, we shall develop expressions only for

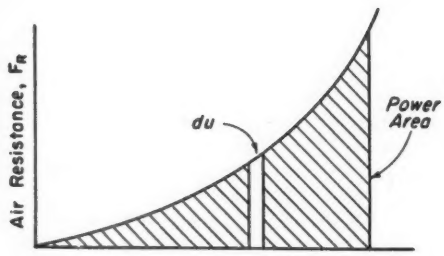

Fig. 4.
Curve illustrating relations between air resistance, particle velocity and power.

the condition of turbulent flow. Reference 5 covers other conditions of motion.

One pound of material in the falling column at some particular location where the velocity is u, a value corresponding to turbulent motion, will generate power in accordance with the following expression:

$$\text{H.P./lb.} = \int \left(\frac{0.44\,\rho\,au^2}{2g}\right)\left(\frac{6}{\pi D^3 \cdot 62.4 \cdot Z}\right)\left(\frac{1}{550}\right)\,du$$

The first group of terms is the resisting force, F_r, or drag of air; the second group describes the number of spherical particles per pound of material; the third term converts to units of horsepower. Integration between suitable limits of velocity and changing the units of particle diameter, gives:

$$\text{H.P./lb.} = \frac{6.92 \times 10^{-3}}{Z\,d_m}\int_{u_{500}}^{u} u^2 du = \frac{6.92 \times 10^{-3}}{3\,Z\,d_m}\left(u^3 - u^3_{500}\right)$$

The lower limit of the integration u_{500} represents the velocity where the intermediate flow relationship ends and the turbulent flow begins (a rather arbitrary point since there is no sharp transition between the two).

It is desirable for practical reasons to replace the velocity terms by distance terms. It is possible to compute the true relationship but no simple equation describes it, and in the present development we employ the relationship $u = \sqrt{2gS}$ for the sake of simplicity, accepting the error thereby entailed. The magnitude of this error is not great in the final result because of the cube relationship between power and air flow and is, moreover, on the conservative side. This substitution results in the following:

$$\text{H.P./lb.} = \frac{6.92\,(2g)^{3/2} \times 10^{-3}}{3\,Z\,d_m}\left(S^{3/2} - S^{3/2}_{500}\right)$$

This represents the power in a one-pound longitudinal slice of the stream and must, therefore, be multiplied by the total weight of material in the entire column. Letting the total weight in pounds be N, and R represent the rate of flow of solid material in pounds per second, the total column weight is given by:

$$N = \int_{S_{500}}^{S} \frac{R\,dS}{u}$$

Here again we assign to velocity, u, the simplified relationship above and obtain:

$$N = \frac{R}{\sqrt{2g}}\int_{S_{500}}^{S} \frac{dS}{S^{1/2}} = \frac{2R}{8.03}\left(S^{1/2} - S^{1/2}_{500}\right)$$

The product of the expression for H.P. per lb. and the above equation for total pounds within the column, leads to the following equation describing total horsepower generated by the entire column:

$$\text{Total H.P.} = \frac{0.29\,R}{Z\,d_m}\left(S^{3/2} - S^{3/2}_{500}\right)\left(S^{1/2} - S^{1/2}_{500}\right)$$

Where, as is usually true, the portion of travel in the preceding zone of intermediate motion is relatively small (i.e., S_{500} is small compared to S), we can neglect the second term in each binomial, then the equation reduces to:

$$\text{Total H.P.} = \frac{0.29\,RS^2}{Z \cdot d_m}$$

Practical Limitations of the Theory

SOME of the limitations of the theory have been indicated in the assumptions given in the preceding development. Some of the others are as follows:

We assume that each particle acts inde-

pendently of its fellows, which supposes that they are completely separated from each other. This is seldom true. More often than not a stream of material falls in a column as a nearly compact mass that is only partly dispersed or aerated.

Another departure from theory is evident from a consideration of the widely varying falling velocities of various sizes of particles in a heterogeneous mixture of crushed material. To what extent do the particles of smaller velocity contribute to the air motion process in relation to that of larger particles hurtling downward through the mass at a velocity several times that of the smaller particles? Other limitations will occur to the reader.

TABLE I.
COMPARISON BETWEEN OBSERVED AIR FLOW INDUCED BY FALLING WATER DROPLETS, ACCORDING TO PRING, ET AL., WITH VALUES CALCULATED ACCORDING TO THEORY

Test No.	Falling Distance to Tank Rim	Calculated Air Flow Based on Maximum and Minimum Falling Distance		Experimentally Determined Air Flow cfm
		Max. cfm	Min. cfm	
16	2.5 ft.	25	11	5
17	3	28	16	17
101	3	28	16	12
18	3.5	30	20	22
19	4.0	31	22	27
102	4.0	31	22	26
20	4.5	34	25	34
21	5	38	29	38
103	5	38	29	35
22	5.5	40	32	46
23	6	41	34	49
37	6	70	57	64

Analysis of Water Drop Tests

A PORTION of the data on air induction by drops of water falling distances up to five or six feet as reported by Pring, Knudsen, and Dennis[4] are shown in the last column of Table I. The two adjoining columns are the values calculated according to theory. The various pertinent dimensions of their tests indicate the air drag pattern to be that of intermediate motion, for which we have derived[5] the expression:

$$\text{Total H.P.} = \frac{48\ R\ S^{1.7}}{Z \cdot d_m{}^{1.6}}$$

which, in conjunction with the earlier equation relating q[3] with H.P. and A, permitted calculation of the air flow values given in the table. Presentation of two values stems from some uncertainty as to the appropriate value of falling distance S. The minimum is that between the droplet source and the rim of the tank, and the maximum is taken as the distance from the droplet source to the bottom of the tank. The fact that the theory is in approximate agreement with the experimental data is gratifying.

Air Induction Laws for Falling Particles

IT IS POSSIBLE to formulate some general laws of air motion analogous to the well-known fan laws by suitable consideration of the relationships previously presented. They may be summarized as follows:

The maximum theoretical rate of air induction due to a stream of falling particles in turbulent motion is proportional to:

1. The cube root of the tonnage rate of solids flow.
2. The cube root of specific gravity of solids.
3. The cube root of particle diameter.
4. The $\frac{2}{3}$ power of solids stream cross-sectional area.
5. The $\frac{2}{3}$ power of falling distance.

For practical purposes turbulent flow may be regarded as confined to particles larger than about two millimeters, and to columns whose falling distance considerably exceeds two or three feet.

[ACKNOWLEDGMENT: The material presented in this paper is a condensation from a chapter in a book, "Plant and Process Ventilation," to be published shortly, by the Industrial Press, 148 Lafayette Street, New York, N.Y. The publishers have courteously granted permission to reproduce portions of that text.]

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Field Studies

OF THE DIFFUSION OF AEROSOLS

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IN RECENT YEARS the engineering profession has become more and more concerned with the problem of atmospheric pollution created by the emission of industrial wastes into the atmosphere. Engineers have come to appreciate the importance of meteorology and climatology in the selection of plant sites, in the choice of plant processes, in the design of plant buildings and stacks, and in the operation of these plants.

Although many hypotheses have been formulated to account for the diffusion of stack effluents under various meteorological conditions, very few experiments on diffusion in the atmosphere have been conducted. An examination of the results reported in the literature clearly shows the need for a program of field testing during known meteorological conditions.

The Experimental Meteorology group at the Hanford Atomic Products Operation, located in eastern Washington, has undertaken such a program. The purpose in this paper is to describe but one phase of the study, the phase in which an aerosol generated at an elevation of 185 feet reaches the ground within a few thousand feet of the point of generation. Although the emphasis in this paper will be on a description of the experimental facilities available and on the techniques employed in the early tests of this program, some of the experimental results will be presented.

Facilities and Techniques

THE MAJOR FACILITY available at Hanford is an open steel tower 410 feet high. This tower is equipped with instruments installed to measure the temperature, wind direction, and wind speed at a number of elevations between ground level and the 400 foot level (Church). The terrain surrounding the tower is gently rolling. The vegetation in the area is desert grass, sagebrush, and Russian thistle.

In the tests to be described the aerosol was an oil-fog emitted from a portable smoke generator mounted at the 185 foot level of the meteorology tower. In the generator a mixture of oil and water is heated and vaporized. As the vapor escapes into the atmosphere it quickly condenses, and a dense white fog or smoke is produced.

Relatively high ground dosages are found when an effluent is emitted from an elevated source during superadiabatic conditions. Experiments are described in which an oil-fog aerosol is emitted from a generator mounted 185 feet above ground on the meteorology tower at the Hanford Atomic Products Operation. The distributions of puffs reaching the ground during two field tests are presented. The modal distance from the tower at which puffs reach the ground is shown to depend on the wind speed.

A sampling technique based upon the fluorescent properties of the oil and used in the determination of oil-fog dosages is described. The oil is collected on a filter, after which it is washed through the filter. The weight of the oil collected is determined by means of a fluorophotometer. The pattern of ground dosages obtained in two field tests in which this technique was employed is discussed.

Presented at the Air Pollution session of the Centennial of Engineering, Chicago, Illinois, September 10-12, 1952.

MR. BARAD is now with the Geophysics Research Directorate, Air Force Cambridge Research Center, Cambridge, Massachusetts.

The following are the advantages in using this aerosol:

1. The generation rate is fairly constant and is easily determined. In the tests to be described the generation rate was about 50 g/sec.

2. The smoke is exceptionally photogenic. Therefore, photographic techniques have been employed for the purpose of providing a qualitative as well as a semi-quantitative picture of the diffusion of the oil-fog plume.

3. The oil-fog particles have a negligibly low settling rate, calculated to be about 10^{-3} cm/sec. Therefore, the vertical motions of the smoke plume are almost entirely a result of turbulent diffusion.

4. The oil fog fluoresces, a property which can be employed in measurements of dosage in field experiments. A field sampler, to be described later in the paper, has been developed.

Smoke Distribution in Unstable Conditions

THE EARLY field tests in this phase of the program were designed to provide a qualitative measure of the ground dosage of oil-fog emitted at the 185 foot level of the meteorology tower during periods in which the lower layers of the atmosphere were convectively unstable.

The aim in a field test conducted at mid-afternoon on August 15, 1951, was to note the position and relative concentration of individual puffs of oil-fog reaching the ground within 1000 feet of the tower. During the test the wind speed varied between 0 and 5 m.p.h. at the seven foot level and averaged 4 m.p.h. at the 200 foot level. The wind direction was extremely variable. The temperature decreased with height, the difference between the 200 and the three foot levels varying between 4.6 and 5.2 F. Superadiabatic conditions of this strength occur frequently on summer afternoons in eastern Washington.

Except for two short periods of complete calm, the oil-fog was emitted continuously during the period. One man operated a theodolite at the 50 foot level of the tower. A second man at that level maintained radio communication with a ground observer a few hundred feet from the tower. The procedure followed by the observation team was to identify a single puff or prominent feature of the smoke plume and to follow it to the ground. The ground observer indicated the time at which the puff reached the ground, its approximate distance from the tower, and the relative density of the smoke. At the same time, the azimuth of the puff and the angle of declination were observed with the theodolite. All these data were recorded by the second man at the 50 foot level.

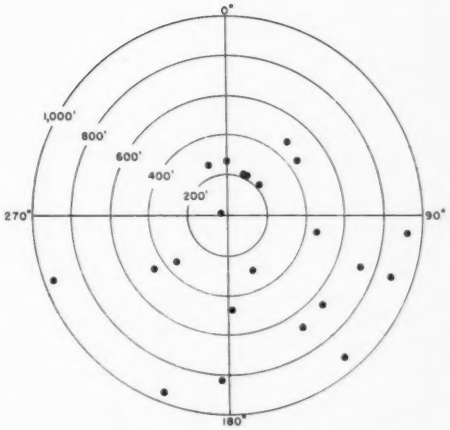

Fig. 1.
Distribution of puffs reaching the ground within 1000 feet of the tower during 45 minutes of generation (August 15, 1951).

The visual observations were plotted to show the distribution of puffs which reached ground level within 1000 feet of the tower during the 45 minutes of oil-fog generation (Fig. 1). Twenty-two puffs were observed to come to the ground within 1000 feet of the tower, while the maximum number of puffs reached ground level at about 400 feet from the tower. The variability of wind direction was reflected in the angular distribution of the puffs, which were observed in all four quadrants.

One week later, on August 22, 1951, another field test of this type was conducted. Although the lower atmosphere was as unstable as it was during the previous field test, the wind direction was much steadier and the wind speeds were stronger. The primary aim in this experiment was to compare the ground pattern observed during steady wind conditions with the pattern observed during the light and variable winds of the earlier test.

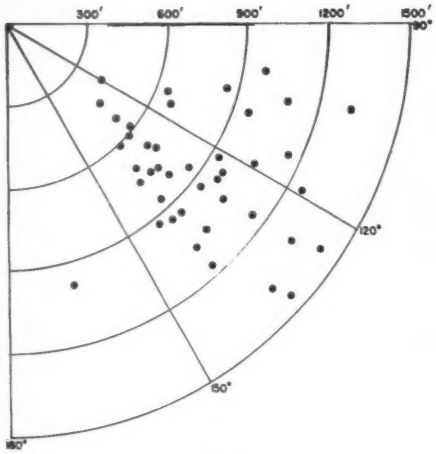

Fig. 2.
Distribution of puffs reaching the ground within 1500 feet of the tower during 51 minutes of generation (August 22, 1951).

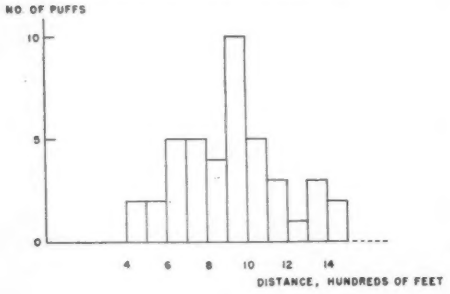

Fig. 3.
Distribution with distance of puffs reaching the ground (August 22, 1951).

The oil-fog was generated from 0810 to 0901, Pacific Standard Time. During this period, the wind direction was northwest. The wind speed at the seven foot level averaged 7 m.p.h. while the wind speed at the 200 foot level averaged 11 m.p.h. The temperature at 200 feet was lower than that at seven feet; the temperature difference varied between 4.4 and 5.2 F.

The visual observations were plotted to show the distribution of puffs which reached ground level within 1500 feet of the tower during 51 minutes of oil-fog generation (Fig. 2). It is interesting to note that 40 of the 42 puffs were confined to a 40° sector, indicating the steadiness of wind direction.

The distances from the tower at which puffs reached the ground were summarized (Fig. 3). Twenty-eight puffs were observed to come to the ground within 1000 feet of the tower during the 51 minutes of smoke generation. The rate of one puff per two minutes was the same as that observed in the earlier test. However, the maximum number of puffs reached the ground, not at 400 feet, but at about 1000 feet. This result is in agreement with theoretical predictions that the distance of maximum ground concentration increases with wind speed.

It is of interest to know the total time during which oil-fog was on the ground within say 1800 feet of the tower. The assumption is made that all puffs, after contact with the surface, move radially off a circular course with the average speed at the seven foot level at the tower. This analysis showed that, in the August 22 test, oil-fog was on the ground within 1800 feet of the tower for 31 of the 51 minutes of generation, or roughly 60% of the time.

Program of Dosage Measurements

RECENTLY a sampling technique based upon the fluorescent property of oil has been developed (Silker and Rieck). The air being sampled is drawn through a high quality asbestos-bearing filter paper. The filter support consists of a one-half inch union with a connection to vacuum afforded by a one-half to one-quarter inch bushing, a one-quarter by one-quarter inch flared half union, and a length of copper tubing (Fig. 4). All of the fittings were sealed to insure against leaks in the system.

The air is drawn by means of a small

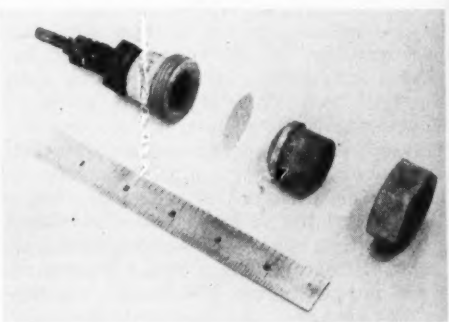

Fig. 4.
Breakdown of filter assembly.

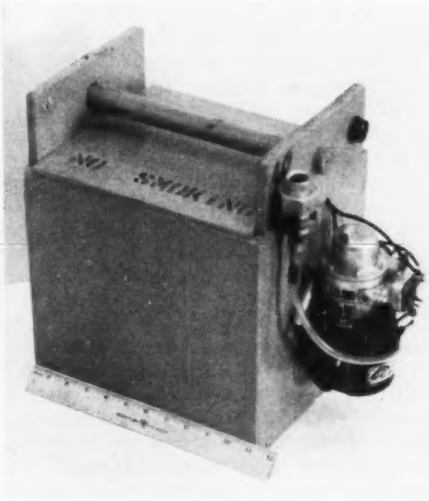

Fig. 5.
Complete portable sampling unit, showing pump, filter holder, and battery case.

pump, which in turn is powered by a six volt storage battery. With the filters attached, the pumps draw about ½ cfm on the average. The flow through each pump is measured before and after each experiment by means of a manometer. The battery, pump, and filter holder are combined in a portable unit (Fig. 5).

Just before the start of a field test the samplers are placed at selected ground positions laid out in a system of polar coordinates. The samplers are turned on prior to the generation of the oil-fog.

After a field test the oil on each filter paper is dissolved in two washings of 10 ml. of ether. The ether is evaporated and the oil remains on a fluorophotometer dish. Fluorophotometer readings are then made. The total amount of oil collected during the test is found from a calibration curve previously determined by taking fluorophotometer readings of known weights of oil which have passed through the generation process. Oil samples of more than 10 μg can be detected by this technique at present.

In a field test conducted on the afternoon of August 6, 1952, oil was generated for a period of one hour at an average rate of 50 g/sec. The mean wind speed at the 200 foot level was 18 m.p.h.; the mean speed at the seven foot level was 7 m.p.h. The temperature at three feet exceeded the temperature at 200 feet by 5 F. The average hourly concentrations in $\mu g/m^3$ were determined at each sampling position. Moving averages in groups of three were computed along each of the four radial distances. The pattern of ground level concentrations may be seen in Fig. 6. The results indicate that for this test the distance of maximum concentration occurred beyond 1600 feet from the source.

A test was conducted during a somewhat similar meteorological condition on September 12, 1952. The mean wind speed at the 200 foot level was 22 m.p.h.; the mean speed at the seven foot level was 14 m.p.h. Again the temperature at three feet exceeded that at 200 feet by 5 F. Average hourly concentrations were determined and three-unit moving averages computed. The pattern of ground level concentrations obtained in this test (Fig. 7) indicated the distance of maximum concentration to exist between 2000 and 2400 feet from the tower or about 11-13 stack heights.

The ratio of maximum concentration to rate of emission of oil-fog was about 2 x 10^{-6} sec/m^3 in the two tests. The results clearly show the need for many samplers if a satisfactory distribution of dosage at ground level is to be expected.

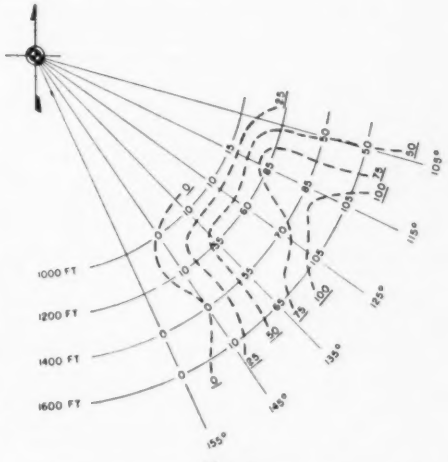

Fig. 6.
Pattern of ground level concentration ($\mu g/m^3$ observed on August 6, 1952.

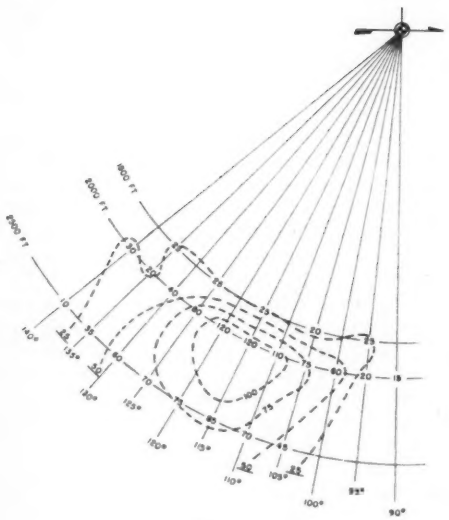

Fig. 7.
Pattern of ground level concentration ($\mu g/m^3$ observed on September 12, 1952.

Limitations

THERE ARE times when engineers are interested in knowing the maximum instantaneous concentration at ground level of a stack effluent. At other times they are interested in knowing the average concentration over periods of one hour or more. It is clear that the sampling technique just described does not provide instantaneous values at each sampler location. However, it does provide a dosage value from which the average concentration can be determined. The average concentration is of particular value to those who wish to check various diffusion hypotheses. In these hypotheses the theoretical concentrations are normally distributed in both the vertical and crosswind directions or can be expressed as the sum of normal distributions. Therefore, to allow for such distributions of concentration, the period of sampling must be sufficiently long. Thus, average concentrations are required.

The field tests conducted at Hanford during superadiabatic conditions indicate that sampling periods of at least one hour are necessary in order to satisfy the normality requirement. In some cases a few hours of sampling may be necessary. However, the diffusion hypotheses also require that the pertinent meteorological parameters exhibit no trend during the sampling period. But largely because of diurnal variations of the meteorological parameters, this no-trend requirement becomes more difficult to satisfy as the sampling period is lengthened. Therefore, the normality and the no-trend requirements conflict.

As a result of this conflict it becomes particularly difficult to evaluate diffusion hypotheses by means of a field testing program conducted during superadiabatic conditions. Nevertheless, in the field tests conducted at Hanford an attempt is being made to conduct experiments which 1) will provide empirical answers for engineers concerned with the problem of air pollution and 2) may provide those evaluating diffusion hypotheses with the experimental data they require.

References

1. CHURCH, P. E., and GOSLINE, C. A.: Meteorological Equipment of the Hanford Engineer Works, Richland, Washington. Bulletin of the American Meteorological Society, Vol. 29, no. 2, 1948.

2. SILKER, W. B., and RIECK, H. G.: A Fluorometric Method for Oil-Fog Determination. Radiological Sciences Department, General Electric Company, Richland, Washington, HW-27626, 1953.

Correction

IN THE article by R. G. MCALLISTER, "Exposure to Menthanol from Spirit Duplicating Machines," 15:26-28, March, 1954, a reference number 3 should be inserted for the material at the foot of the first column of page 27 and the following added to the References at the end of the article:

3. GOSS, A. E. and VANCE, G. H.: Methanol Vapors from Duplicating Machines May be Health Hazard. *Industrial Hygiene Newsletter*, September, 1948, p. 15.

Safe Handling Procedures for Compounds Developed by the Petro-Chemical Industry

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N. W. JACOBSEN, Supervisor, Safety and Industrial Hygiene
Shell Development Company, Emeryville, California

THIS PAPER describes the methods used in establishing safe handling procedures for petro-chemical compounds originating in the Shell Development laboratories. Problems concerned with safe handling of chemicals in a research and development laboratory differ from those in a manufacturing company. These differences occur because the number of persons exposed is fewer, the quantity of compounds is smaller, the time of contact is shorter, the number of compounds is greater, procedures are more varied, and information about the toxicity is less complete and frequently lacking.

In the Shell Development Company, it is management's responsibility to see that conditions are as safe as it is practicable to make them, and to insure that persons working with new compounds, processes and applications, know the hazards involved and the precautions to be taken. To meet this responsibility effectively, management depends upon information and recommendations prepared by the following staff groups: (1) the Safety Board, composed of members of management whose decisions delineate policy relating to industrial hygiene and safety matters; (2) the Safety Committee, a group of technical and non-technical personnel appointed by the manager of the laboratories, to study specific safety problems and review recommendations which are made by its subcommittees; (3) Departmental Safety Committees, which are appointed by, and are responsible to, the Department Heads.

Presented at the Sixth Annual Industrial Health Conference, Houston, Texas, October 1, 1953.

DR. HINE is also Associate Clinical Professor of Pharmacology and Toxicology, University of California, School of Medicine, San Francisco, and Associate Clinical Professor of Industrial Toxicology, School of Public Health, University of California, Berkeley.

In addition, professional personnel, engineers trained in industrial hygiene and safety, and the toxicologist, serve in an advisory capacity. Upon these persons falls the immediate responsibility of evaluating hazards and making recommendations for safe handling procedures. The extent to which each of these groups and persons may participate depends on the magnitude of the problem.

The problem is defined in terms of (1) toxicity of the compound, (2) the number and training of exposed persons, and (3) industrial hygiene aspects of preparation and development.

Requests for investigation into the hazard of a process or the toxicity of a new compound may originate from several sources. The most usual source is by personal request from a chemist or engineer in charge of a project. This exchange of information is usually carried out on an informal basis unless the number of persons involved is sufficiently large, or the toxicity of the compound is sufficiently great, to warrant its investigation by a subcommittee of the Safety Committee. In the latter case, formal recommendations are made by the subcommittee following its interviews with the toxicologist, the industrial hygiene and safety engineers, and following their inspection of the process. Requests for information may also originate from the Market Development Department. This department coordinates and disseminates toxicological information to the other Shell Companies and potential customers. The majority of experimental work in toxicology is coordinated through this department. Reports made to this group are usually more formal and represent a more studied opinion. Occasionally, investigations are origi-

nated by the toxicologist as a result of his findings of intoxication in exposed personnel. More extensive animal testing may be subsequently undertaken and industrial hygiene practices are reviewed together with existing engineering design and safe handling precautions.

As has been outlined, the first step in establishing safe handling procedures is to define the toxicity of the compound. In the case of older compounds, this may already be established and reference can be made to published data of experimental and clinical nature. However, with new compounds, there are but two approaches: (1) to explore the compound in terms of theoretical, biochemorphology (relation of chemical structure to biological activity) and (2) to apply experimentation. Biochemorphological studies require an intimate knowledge of pharmacology, biochemistry and pathology. This is the method of preference when there is a limited quantity of compound, when it is closely related structurally to well known compounds, or when it is in a stage of embryonic development. Toxicity data of an experimental nature are developed by studying the effects of the compound, usually on laboratory animals and occasionally on man. Since 1936, Shell Development has maintained a research program with a nearby medical school through which toxicological evaluations can be made. The extent of the toxicological investigation depends upon the stage of development of the compound in the research laboratory and the need for additional toxicological information. In the early stages, information of a simple nature as to acute toxicity classes and skin- and eye-irritating properties is generally all that is required. In other words, an attempt is made to integrate the development of toxicological data with the orderly market development of the agent. In preliminary toxicological tests, information is obtained on the approximate quantity of the chemical which will kill a laboratory animal. These tests are made by exposing an animal to the vapors, placing the compound on the skin or in the stomach. Having obtained this information, the data are then translated by one of two methods: either by reference to procedures similar to those described by Hodge and Sterner* (Table I), or by reference to compounds familiar to the chemist through previous experience. In the first method, one defines the toxicity of the compound, using common terms, with reference to the quantity necessary to produce death in a rat or rabbit by a specified route of administration (Table I). As the development of the compound passes to the pilot plant stage, additional information is obtained. Experiments are then designed to determine the effects of repeated exposures to varied concentrations of dusts and vapors, repeated contact with the skin and repeated daily ingestion of small quantities in the diet. By these tests an attempt is made to define the following levels of exposure: (1) those which produce no significant change in behavior, activity and growth of an animal, (2) those which

*Hodge, H. C., and Sterner, J. H.: Tabulation of Toxicity Classes. *Amer. Indust. Hyg. Assn. Quarterly*, 10:4, 93 (December), 1949.

Table I.
Combined Tabulation of Toxicity Classes

		Various Routes of Administration			
Toxicity Rating	Commonly Used Term	LD50 Single Oral Dose Rats	Inhalation 4 Hr. Vapor Expos. Mortality of 2/6-4/6 Rats	LD50 Skin Rabbits	Probable Lethal Dose for Man
1	Extremely Toxic	1 mgm. or less/kg	<10 ppm	5 mgm. or less/kg	A taste, 1 grain
2	Highly Toxic	1-50 mgm.	10-100	5-43 mgm.	1 teaspoon 4 cc.
3	Moderately Toxic	50-500 mgm.	100-1000	44-340 mgm.	1 oz. 30 Gm.
4	Slightly Toxic	0.5-5 Gm.	1000-10,000	.35-2.81 Gm./kg	1 pint 250 Gm.
5	Practically non-toxic	5-15 Gm.	10,000-100,000	2.82-22.59 Gm./kg	1 quart
6	Relatively harmless	15 Gm. and more	>100,000	22.6 or more Gm./kg	>1 quart

will just produce abnormal organ weight changes, minimal tissue damage or minimal change in the function of an organ, and (3) that which is incompatible with survival of a considerable portion of the test species. These tests may run from 30 to 90 days. Compounds which are assured of commercial production will be given even more critical evaluation in terms of levels producing different types of injury over extended periods of time. In addition to defining the relative toxicity of a compound, an attempt is also made to ascertain its mechanism of action, probable detoxication and rate of storage and elimination from the body. This information serves as a basis for developing rational antidoting procedures. At an early date, information is made available to the Company's nursing staff as to suitable first aid measures and to the attending panel of physicians as to desirable methods of treatment of exposed personnel. In addition to the methods of animal experimentation, at times controlled experiments are carried out with human volunteers. By such direct measures, information may be obtained relative to the minimal quantity of vapors required to produce threshold sensory changes, such as, olfactory stimulation, eye and mucous membrane irritation, central nervous system effects (or possible skin-irritating and sensitizing properties). Such information is useful in helping establish suitable maximum allowable concentrations for the compound (and in defining the potential dermatological problem).

The second approach is to analyze the problem in terms of the number and qualifications of personnel; for example, is it a laboratory, an intermediate scale or a semi-plant problem? Initial studies are usually conducted or directed by a few skilled professionals working under excellent laboratory conditions. Consequently, exposures at this level are minimal. These persons are expected to familiarize themselves with the hazard of their operation and to take commensurate precautions. If they desire consultation on safe handling, the services of the health conservation group are available. Regulatory measures for this group are largely unnecessary. When a larger number of persons becomes involved in a problem, the degree of supervision from the health and safety standpoint must be increased. For example, if requests are made of other departments for investigation of the physical and chemical properties of the compound, some information must be transmitted with the sample as to its toxicity, skin-irritating properties and explosibility. When the compound progresses to the pilot plant stage, a study is made by both the departmental Safety Committee and, if requested, by subgroups of the Safety Committee as well.

The final step in definition is to survey the industrial hygiene aspects of preparation and development. This is the responsibility of the supervisor of safety and industrial hygiene. His responsibilities in the initial phase of an investigation are usually to suggest what protective clothing is suitable and whether the process demands a barricade or special ventilation. In intermediate and pilot stage operations, additional methods for control are investigated and recommendations made. These may include techniques for waste disposal, procedures for decontamination, and selection of additional protective equipment. At present, air analyses for special contaminants are not carried out on a routine basis; however, determinations of this type can be performed in instances where there have been specific complaints or when physical examination through the Company's health conservation program has uncovered evidence of intoxication.

General compulsory health appraisals are not conducted on a Company-wide basis; however, all personnel in the semi-plant areas and those exposed to unusually hazardous substances are covered in our health conservation program. As a part of this program, a preliminary assessment of the individual's status is made prior to his period of exposure, and re-examinations are conducted at intervals commensurate with the degree of hazard. When possible, data obtained from these examinations are coordinated with environmental findings.

The clinical laboratory examinations which are a part of this health evaluation program usually include routine blood and urine analysis, bleeding and clotting time and icterus indices determinations. Liver and kidney function tests are done whenever indicated. Biochemical tests which indicate the quantity of toxin in a body fluid or

excreta, or alterations in normal biochemistry, are utilized more rarely. These examinations also provide a check on the engineering design and prescribed protective measures. Another method which has been found useful in early assessment of possible intoxication is to require all personnel with complaints associated with chemical exposure to report immediately to the toxicologist for interview and examination. A record of these complaints and findings is crossfiled under the suspected agent. This facilitates determination of the number and kind of complaints associated with any particular chemical or process. We usually describe the number of complaints and the cases of alterations in physical and laboratory findings in terms of man hours of exposure. In computing rates, we find the potential hours of exposure can easily be ascertained by reference to payroll cards, since cost accounting is kept in terms of man hours expended on a particular project.

So far, methods of determining the degree of hazard encountered in particular processes or from handling specific chemical substances and the methods used in recognition of resulting altered physiology have been presented. To establish safe handling procedures, it is necessary to establish engineering control and adequate medical supervision and care; however, this is not enough.

The individuals concerned must be cognizant of specific precautionary methods and impressed with the necessity for applying these at all times. This is accomplished by formal and informal discussions. The most common method of disseminating information is by interview with the Department Head and those persons who will be directly concerned in the project. Close liaison is maintained with the head of Experimental Plants so that as new compounds are scheduled for manufacture the Safety Engineer and the First Aid group may be alerted to the necessity for carrying out their functions. Occasionally, discussions may take a more formal turn and a group meeting will be held on a conference basis, with discussion augmented by demonstration of toxic effects in animals. At the request of certain department heads, their Safety Committees have received lectures on the general aims of the health conservation program and the methods for establishing safe handling of compounds, to better acquaint their staff with this activity.

A safety manual has been prepared for general use and it is the responsibility of every employee who is in laboratory or development work to become familiar with the procedures outlined in this manual. There is a general section on chemical hazards and background information on toxicity; this includes a list of the maximum allowable concentrations for a number of compounds found in the laboratory. Certain compounds are designated as being so hazardous that they require a Hazardous Work Permit prior to their use. In this way, it is possible for the Safety Engineer to inspect an extremely hazardous process, or one involving very toxic chemicals, before any exposure has occurred. The final method for dissemination of information is by circulation of current abstracts pertaining to safety, industrial hygiene and toxicological matters among all professional personnel. These abstracts are prepared from current literature by a rotating committee, reviewed by the toxicologist, and disseminated as an addendum to the lists of new material available in the library.

The results of this program have been most satisfactory. No fatalities have occurred from chemical exposure in the entire history of the Shell Development Company. Intoxications from exposure to compounds have been kept to a minimum, as has lost time due to injury. Finally, a background of know-how in handling compounds safely has been developed, which can be transmitted to the manufacturing companies and to potential users of the compounds.

THE NEW YORK UNIVERSITY, Post-Graduate Medical School, Department of Industrial Medicine together with the College of Engineering presented a course in Air Pollution, May 10 to 21. This comprehensive two-week training period included lectures on all phases of Air Pollution, presented by recognized authorities in the field.

Dust Sampling
BY THERMAL PRECIPITATION

I. G. POPPOFF
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The theory of thermal precipitation is summarized and its applicability to the operation of aerosol collectors is considered. The essential characteristics of thermal precipitators are discussed. Results from limited investigations of the operating characteristics of one type of thermal precipitator are included.

SIMULTANEOUSLY with the increased interest in dust* particle collections for the evaluation of hazards from noxious fumes, explosive dusts, and powdered insecticides, there has developed strong evidence that current standard collection methods are inadequate. Most of the commonly used instruments are inefficient for small particles, particularly when the particle diameters are less than 1 or 2 μ. A notable exception is the thermal precipitator, collection efficiency for which increases with diminishing particle size. The thermal precipitator produces almost complete precipitation of particles with diameters below 1 or 2 μ. In this instrument the sample is not agglomerated and the precipitating force is gentle enough to prevent shattering of the particles or tearing of the Formvar surface of the electron microscope screens upon which the specimen can be directly collected. The advantages of this instrument for use in particle size studies and particularly in the preparation of dust samples for electron microscopy suggest a need for a general discussion of the theory of thermal precipitation and the operation of thermal precipitators.

Theory

IT IS KNOWN that if a hot body is suspended in a wind-free dust-laden atmosphere, a dust-free space a fraction of a millimeter wide immediately surrounds the body (Fig. 1). This phenomenon is explained theoretically as an interaction between the dust particle and the steep thermal gradient which causes the particle to be accelerated away from the body. Thus, if a surface that is cold with respect to the hot body, is placed within the dust-free space, a particle passing between the hot body and the cold surface will be precipitated on the cold surface.

The dust-free space surrounding a hot body was first reported in 1870 by Tyndall,[1] who gave two possible explanations of the phenomenon. He surmised that the dust was destroyed by the heat or that the body warmed the surrounding air which rose dragging the dust after it. Rayleigh,[2] dissatisfied with this explanation, repeated Tyndall's experiments in 1882. His explanation was that "the curvature of the streamlines near the surface of the obstacle was such as to cause the heavier particles to be thrown outwards away from the body and thus to leave a thin layer free from dust."

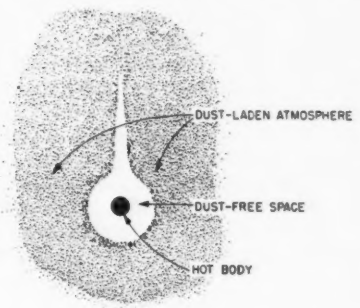

Fig. 1.
Dust free space about a hot body.

The work here reported was done at the U.S. Naval Radiological Defense Laboratory by MR. POPPOFF, who is now with Stanford Research Institute, Stanford, California.

*This includes all small particulate aerosols that are sometimes classified as smokes, fumes, and dusts.

The phenomenon was studied more thoroughly in 1884 by Aitken[3] and by Lodge and Clark.[4] They reported independently that the dust-free space was probably created by a repelling force which resulted from the molecular bombardment of dust particles in the heated air surrounding the hot body.

The literature shows two theoretical approaches to the problem of describing the thermal repulsion phenomenon quantitatively. To avoid a possible misunderstanding, it should be noted that many authors consider both approaches as ramifications of the radiometer theory. It is felt, however, that a clear distinction should be made, since one approach considers only the molecular bombardment of the particle, while the other takes into account the important effect of heat conduction in the particle and the gas. Therefore, for purposes of comparison, the molecular bombardment and radiometer theories will be treated as separate concepts in this presentation.

In 1936, Cawood[5] based his investigation of the dust-free space about a hot body on the molecular bombardment theory. He considered the force on a particle in a small cylinder of gas and developed an expression for the velocity with which the particle is repelled in a thermal gradient.

$$V = \frac{1/2\ p\ \frac{dT}{dx}\ \frac{L}{T} - \frac{RT}{N}}{6\pi\,\eta\,r}\,\pi r^2\,(1 + \frac{AL}{r}), \quad (1)$$

where P = pressure,

$\frac{dT}{dx}$ = thermal gradient,

L = mean free path
T = absolute temperature
R = gas constant,
N = number of molecules per cm^3
A = constant,
η = viscosity of gas, and
r = radius of particle.

Values computed with this formula agreed within an order of magnitude with those found by experiment. According to the molecular bombardment theory, convection currents should overshadow molecular forces for large particles. This fact was confirmed by observation.

A more successful approach to the problem of the dust-free space about a hot body considered thermal repulsion as a radiometer phenomenon. As early as 1825, Fresnel noted the effect of radiation on a body suspended in a gas. Since that time, many investigators have attempted to derive equations describing the radiometer effect observed with the classical vane radiometer. The first equation that successfully agreed with experimental observations was derived by A. Einstein[6] in 1924. The derivation was based on heat flow in a simplified model and yielded the following expression for the force per unit length of the vane.

$$F' = -\frac{1}{2}\left(\frac{PL^2}{T}\right)\frac{dT}{dx}. \quad (2)$$

In 1880, Maxwell developed an equation for the force on a radiometer vane in a high pressure atmosphere. Although this equation was not even in qualitative agreement with experiment, a more rigorous derivation based on Maxwell's work was developed by Epstein[7] in 1929. His value for the force on a radiometer vane in a high pressure atmosphere was:

$$F = -\frac{9\pi r\,H'}{2\,H' + H''}\,\frac{\eta^2}{\rho T}\,\frac{dT}{dx}, \quad (3)$$

where F = force on the particle,
H' = heat conductivity of gas,
H'' = heat conductivity of particle,
and ρ = density of gas.

Particles having diameters of several microns or less acquire terminal velocities in distances less than their diameters. If Z is the mobility of the particles, their velocities can be described by:

$$V = FZ. \quad (4)$$

In a medium rendered inhomogeneous by a steep thermal gradient, Z is dependent upon the ratio L/r as follows:

when L/r is small,

$$Z = (1 + AL/r)/6\,\pi\,\eta\,r; \quad (5)$$

when L/r is large,

$$Z = (A + B)\ L/6\,\pi\,\eta\,r^2; \quad (6)$$

when L/r has an intermediate value,

$$Z = \left[1 + L/r\ (A + Be^{\frac{-cr}{L}})\right]/6\,\pi\,\eta\,r, \quad (7)$$

where $A = 1.23$,
$B = 0.41$, and
$c = 0.88$

In 1946 Rosenblatt and LaMer[8] obtained the following general equation for the velo-

city of a particle in a thermal gradient;

$$V = \frac{-17.9}{2 + H''/H'} \frac{PL^2}{T} \frac{dT}{dx}$$

$$\frac{1 + \frac{L}{r}(A + Be^{\frac{-cr}{L}})}{6\pi\eta}. \qquad (8)$$

This relation follows from the use of Equations (3) and (7) in (4) together with the relationships,

$$\eta = 0.499\ \rho\ \overline{V}\ L, \text{ and } \rho\ \overline{V^2} = \frac{8P}{\pi},$$

where $\overline{V}$ is the root mean square molecular velocity. These workers measured the velocities of droplets of tricresyl phosphate in a thermal gradient and found remarkable agreement with this equation for various values of pressure, thermal gradient, and droplet radius. The validity of this relationship was confirmed again in 1952 by Saxton and Ranz,[9] who investigated the effect of particle size and thermal gradient on the repulsive force. The radiometer theory also predicts a "thermal creep" effect which causes a streaming of the gas from the cold to the hot side of the particle. This was observed by Gerlach and Schutz[10] in 1932.

From the foregoing evidence, it certainly appears that the radiometer theory provides the more satisfactory explanation of the dust-free space surrounding a hot body.

Development of the Thermal Precipitator

PROBABLY the first record of thermal precipitation was the work of Lodge and Clark,[4] who obtained a pattern of the dust-free space surrounding hot bodies by precipitation onto a glass slide at an angle to the body.

Aitken,[3] working independently, devised two "thermic filters." One model was composed of a hot platinum wire between two glass plates. There was approximately 1 mm. separation between the wire and the plates. The air was drawn between the plates and the dust precipitated on them opposite the wire (Fig. 2). This design is the basis of the most popular types of precipitators in use today. The other model consisted of two concentric tubes, one heated by steam or open flame, and the other cooled with running water. The air was drawn through the space between the tubes, the dust precipitating on the cool tube (Fig. 3). A successor to this model is also in use today.[11] It was reported that the "filtering" action was more effective than cotton wool filters, but slower.

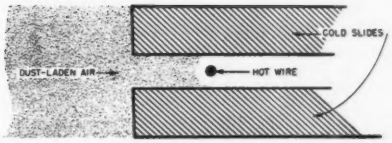

Fig. 2.
Parallel plate thermal precipitator.

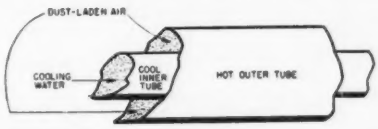

Fig. 3.
Concentric tube thermal precipitator.

The first reported use of thermal precipitation for the sampling of particles for subsequent study was by Lomax,[12] who used an instrument consisting of two parallel plates through which the sampled air was drawn. The lower plate was cool and covered with a glass slip while the upper plate was heated to approximately 110° C. It was reported that the particulate matter was collected without coagulation or size discrimination. The instrument was later modified by Whytlaw-Gray and Lomax[12] who used two hot wires in a plane midway between two cool plates. This modification did not quite produce 100% efficiency. Green and Watson,[13] searching for an instrument with a high collection efficiency for small particles, reasoned that the Whytlaw-Gray and Lomax precipitator could be operated at 100% efficiency with a single wire if a higher temperature were maintained. The instrument was accordingly modified and found to be 100% efficient for particles up to 20 μ in diameter when compared with their analysis by an ultramicroscope.

Watson,[14] studying the characteristics of the dust-free space surrounding bodies of various shapes, determined the following empirical formulas relating the thickness of the dust-free space to excess temperature, pressure, and shape of body.

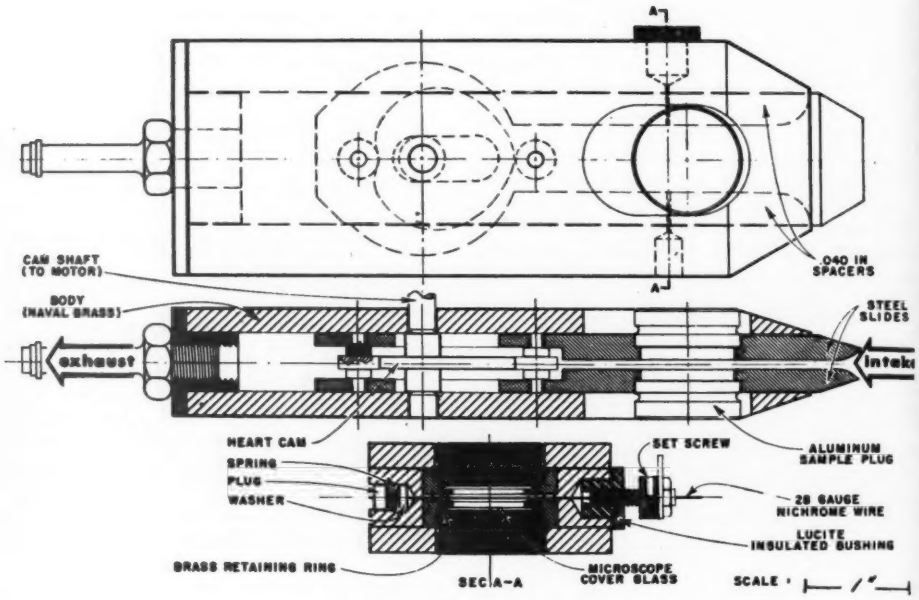

Fig. 4.
Oscillating thermal precipitator.

$$A = L \ominus H^{-0.38}, \quad (9)$$

where

A = thickness of dust-free space,
L = 7.6×10^{-5} for horizontal rods,
L = 15.6×10^{-5} for vertical planes,
$\ominus$ = temperature excess over ambient air in °C,
H = convective heat loss from unit area of body surface, and
$H = C \ominus^{1.25}$, where C is a constant.

The constant C varies with the size, shape, and orientation of the body. The five cases listed were investigated by Watson.

Shape and Orientation	Cx10⁴
Vertical copper plane, 6.0 cm high, 3.0 cm wide	1.03
Vertical copper plane, 3.1 cm high, 3.0 cm wide	1.53
Horizontal copper rod, 0.9 cm diameter	0.93
Horizontal copper rod, 0.46 cm diameter	1.25
Horizontal copper wire, 0.0254 cm diameter	5.87

The investigation of the pressure dependence of the dust-free space resulted in the following relationships.

$A \propto \ominus^{0.52} P^{-0.61}$, for plane vertical surface.
$A \propto P^{-0.65}$, for a horizontal carbon rod.
$A \propto P^{-1.0}$, for a vertical platinum ribbon.

It was also noted by Watson that the collection was size fractionated in the direction of flow. As can be seen from Equation (8), the relationship between the repulsion velocity and particle size is such as to cause a size gradation in the deposit. Even though this effect can be tolerated in optical examinations of samples, it cannot be tolerated in analyses with the electron microscope. Since the area viewed by electron microscopy is very small compared with the width of the deposit, size frequency determinations are not representative of the sample, but are highly dependent on the position of the electron microscope specimen screen both in the collector and in the microscope.

The Porton Laboratories developed an oscillating thermal precipitator to overcome this size fractionation. In their instrument, the sample collection slide is oscillated back and forth in the direction of the flow. Since the period of oscillation is shorter than the sampling time, the sample should be thoroughly mixed with respect to particle sizes

and the size frequency determinations should be representative of the sample. An improvement of the Porton design was made at the University of Rochester by Wilson.[15] This latter design, with the addition of an improved wire suspension assembly and closer machining tolerances, is used at the U.S. Naval Radiological Defense Laboratory (Fig. 4) for sampling fine aerosols.

Sampler Characteristics

THE EFFECTIVE use of dust sampling instruments and critical evaluation of the collected sample necessitates an appreciation of the characteristics and limitations of the particular instrument used. For thermal precipitators, the following characteristics should be considered: (1) sampling rate, (2) oscillation, (3) temperature, and heat conductivity, and (4) collection efficiency as a function of particle size.

Sampling Rate: The greatest weakness of thermal precipitators is their low sampling rate. Ordinarily, 6 to 10 cc./min. is the acceptable rate for the models discussed above, although some investigators have reported designs suitable for higher sampling rates.[16] The limiting factors are the narrow flow channel past the hot element (ordinarily 0.010 to 0.015 in. on either side of the wire) and the low linear velocity required for effective precipitation (approximately 0.04 fps).

Oscillation: The moving slides in an oscillating type of precipitator apparently set up extraneous air currents in the narrow channel between the hot body and the sample slides. These currents increase the linear velocity of the particles moving through the thermal gradient. If the added velocity imparted to the particles is great enough, a decrease in sampling efficiency results. The maximum allowable oscillation rate may be quite low, depending on the particular geometry encountered. For example, work at this Laboratory has shown that oscillation rates greater than 1 cpm resulted in reduced collection efficiency for the model shown in Fig. 4. This was evidenced by collection in a second precipitator sampling the exhaust of the test instrument.

Temperature, and Heat Conductivity: The effect of temperature on collection efficiency can best be shown by considering the relationship between wire temperature and the thermal conductivity H″ of the material being precipitated. From Equations (3) and (4) it is evident that,

$$V = -Z \frac{9 \pi r H'}{2H' + H''} \frac{\eta^2}{\rho T} \frac{dT}{dx}. \qquad (10)$$

This expression shows the velocity of repulsion of the particle to vary inversely as its thermal conductivity[17] and directly as the factor $\frac{1}{T} \frac{dT}{dx}$

Since collection efficiency in a given precipitator is a function of the repulsion velocity, it is evident that the same collection efficiency for two different aerosols can be achieved by adjusting the temperature of the wire to compensate for the difference in thermal conductivities. The results given below, obtained with the instrument shown in Fig. 4, illustrate the applicability of this relationship.

Aerosol Material	Thermal Conductivity at 20 °C (cal/cm/sec/°C) (a)	Wire Temperature Necessary for Complete Precipitation (°C)	Temperature Differential, Wire to Slide (°C)
Aluminum Oxide	0.0081 (b)	280	230
Sodium Chloride	0.0136	560	510

(a) Special Paper No. 36, Geological Society of America.
(b) For corundum crystal, H = 0.0066 parallel to axis, and H = 0.0096 perpendicular to axis. An average value of H = 0.0081 was used.

Since H′ « H″, Equation (11) indicates that the ratio of the quanity $\frac{1}{T} \frac{dT}{dx}$ for the two aerosols given in the above Table should approximate the ratio of the thermal conductivities, i.e., 1.68 to 1. Actually the ratio was 1.7 to 1, which is certainly surprisingly good agreement, considering the assumptions necessary to make these measurements. This discussion suggests that if the temperature necessary for the complete precipitation of a test aerosol of known thermal conductivity and appropriate size range is once determined, the optimum operating temperature to be used in the collection of any other aerosol can be calculated. For such calculations it must be assumed that the average temperature of

the space between the wire and slide is the mean of the optimum operating temperature of the wire and the temperature of the slide. Furthermore, the average temperature of the space between the wire and slide is obtained from:

$$\frac{H_t}{H_s} = \frac{\left[\frac{1}{T}\frac{dT}{dx}\right]_t}{\left[\frac{1}{T}\frac{dT}{dx}\right]_s}, \qquad (11)$$

where

H_t = thermal conductivity of test aerosol,
H_s = thermal conductivity of another aerosol,
T = average temperature of the space between the wire and slide in °K, and
$\frac{dT}{dx}$ = thermal gradient.

Since the thermal conductivities[18] of most common minerals are smaller than that of sodium chloride, any precipitator that works effectively with a sodium chloride aerosol should precipitate almost any aerosol except those composed of pure metals. Whenever it is possible, the optimum operating temperature should be determined beforehand because of the power consumption problem in portable equipment. Frequently such determinations cannot be made because of the paucity of thermal conductivity data.

Collection Efficiency as a Function of Particle Size: One of the most important characteristics of any dust sampling device is its collection efficiency as a function of particle size. No critical evaluation of samples is possible without some knowledge of this characteristic. Whytlaw-Gray and Patterson[12] described the precipitator as an instrument "used to sample particulate matter without coagulation or size discrimination." This is known to be true only for small particles, however. Green and Watson[13] found a collection efficiency of 100% for particles up to approximately 20 μ. Lauterbach[15] has reported 99.9+% efficiency for particles <1 μ with flow rates up to 20 cc./min. with their oscillating model. Preliminary investigations of the precipitation efficiency for particles >1 μ using alumina powder in the size range 0 to 20 μ at a flow rate of 7 cc./min. at this Laboratory gave the following data:

Particle Size (μ)	Collection Efficiency (percent)
1- 4	100
4- 6	99
6-10	98

In order to minimize the effect of gravity, which would result in the subsidence of particles greater than 4 to 5μ at these low velocities, the precipitator and aerosol stream were aligned along a vertical axis.

Summary

ALTHOUGH the phenomenon of thermal precipitation has been known for almost 70 years, interest has been shown in the exploitation of this effect only since the development of the electron microscope. The effect provides an ideal sample for electron microscopic analysis because the thermal precipitator collects small dust particles without agglomeration or size discrimination, at least below 10 μ, and its action is gentle enough to allow precipitation directly and without damage onto Formvar-covered electron microscope specimen screens.

On the other hand, there are still the disadvantages of low sampling rates and possible size discrimination in the large particle range >10 μ. Also, there is a pronounced lack of quantitative data regarding such important points as optimum flow rates, size discrimination, and the effects of temperature, thermal gradient, and thermal conductivity on collection efficiency. It is hoped that further investigation of thermal precipitation will provide even more adequate means of collecting microscopic and submicroscopic particles.

[Acknowledgement is made to N. H. FARLOW for aid in making the measurements reported in this paper and to JARVIS TODD for invaluable guidance in the preparation of the manuscript.]

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17. Recently confirmed independently by other investigators. See SAXTON and RANZ, op. cit.
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Stripping Specifications

DR. WILLIAM A. HAMOR, Director of Research, Mellon Institute, advises the AIHA QUARTERLY that S. A. BRADLEY, Senior Fellow, has presented a report of the investigational activities and accomplishments of the Mellon Institute Multiple Fellowship on Mine-Acid Control. The Fellowship has assisted in the formulation of procedures for experimental stripping specifications issued by the Sanitary Water Board of the Commonwealth of Pennsylvania and has gathered much information on the effectiveness of these regulations as they apply to the stripping operation carried on under the Experimental Stripping Permits.

The report discusses the nature and composition of mine discharge; the source and reactions by which it is formed, including the role of bacteria; the methods by which the acid is carried through and from the mines; the relationship between concentration and volume of flow on a seasonal basis, the seasonal effect on streams; and the effect of self-purification on streams. The report concludes that the water which is discharged from coal mines is similar to that which normally flows through underground water channels, except for whatever it gathers in its route through the mine. Much can be accomplished by a proper layout in drainage channels in a mine to prevent "pick-up" of the acid by the water, and in open pit or strip mines by water control plus segregation of spoil, which latter can be eventually buried when backfilling.

It is believed that any coal which can be economically mined by stripping can be mined without harm to adjacent streams. The general principles embodied in the Experimental Stripping Specifications of the Sanitary Water Board are the essential factors namely, they are (1) Keep the pits as dry as possible at all times. (2) Segregate the sulfuritic spoil and place it so that it can be replaced in the bottom of the pit. (3) Back-fill to a depth of several feet above the coal seam in the high wall and grade in such a manner that surface water does not form pools above the sulfuritic materials or in the pits. In cases when the coal seam is well below the level of adjacent streams, this may not be necessary.

Where the coal seam is below the water table, the pits may often be allowed to fill with water. It is possible that some pits above drainage level may also be allowed to fill with water if the earth in which they are formed is sufficiently impermeable to hold a proper level. Though no specific method of abatement of acid discharge can be recommended, there are many things which can be done to prevent the increase in acid discharge which in the past has been roughly proportional to the increase in mined out areas. Much more cooperative effort by scientists and operators is required if pollution of our decreasing water supply is to be satisfactorily abated.

American Industrial Hygiene Association

— FIFTEENTH ANNUAL MEETING —
Chicago, Illinois

THE Fifteenth Annual Meeting of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION was held April 26-29, at the Hotel Sherman, Chicago, Illinois. There were 462 members registered. Total registration of the Industrial Health Conference was 1,981 of which number 198 were guests.

On Monday, April 26, AIHA members were given a choice of four tours and a good representation participated in each tour.

The joint meeting held with the American Conference of Governmental Industrial Hygienists on April 27 and with the Industrial Medical Association on April 28, was well attended, several hundred being at each of these sessions.

A total of 59 papers were presented at concurrent sessions on Air Pollution; Engineering; Chemistry and Analysis; Toxicology and Radiation. These sessions were of great interest with peak attendance at each of them being about equal.

At the annual banquet held in the Louis XVI Room of the Hotel Sherman, FRANK A. PATTY delivered the Donald E. Cummings Memorial Lecture. The lecture, which most adequately reviewed the fifteen years of progress of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION—with a look into the future, was aptly entitled, "Now We Are Fifteen."

At the April 27 Board of Directors meeting, the resignation of the Executive Secretary, HENRY F. SMYTH, JR., was announced. The resignation becomes effective June, 1955.

Approximately 200 members attended the business meeting. One amendment to the Constitution and one to the By-Laws were unanimously accepted at the meeting. The Constitutional amendment makes it possible for organizations interested in industrial hygiene to enjoy membership. The amendment to the By-Laws introduces a new section which permits the Board of Directors to "elect as Contributing Members such organizations as may apply for this status. . . ."

Frank A. Patty (left) receiving the 1954 Donald E. Cummings Memorial Award from retiring President Henry Field Smyth, Jr.

The 1955 Industrial Health Conference will be held in Buffalo, New York, April 23-29, 1955! Plans are already underway to make this another interesting and informative meeting.

Noise for Sale

THE ARTICLES from the Conference on Factory Noise which were published in the March, 1954 issue of the AMERICAN INDUSTRIAL HYGIENE ASSOCIATION QUARTERLY (pages 29-68) have been reprinted in an attractive booklet called "Facts on Factory Noise—Practical Approaches to Plant Noise Suppression." Copies may be obtained at 75¢ each from Associated Industries of New York State, Inc., One Elk Street, Albany, New York. On orders over 100 copies, the unit price is 50¢.

♦ President's Page

FOR ANY professional organization to progress and strengthen its position, it must fulfill the needs of its membership, and perhaps more important, the needs of the people and organizations which its membership serves. Is the AIHA meeting these needs?

When AIHA was formed in 1939, one of the objectives set forth was "to increase the knowledge of industrial hygiene through interchange and dissemination of information." This objective is presently being fulfilled, at least in part, through the sponsorship of annual meetings and publication of the QUARTERLY. In addition, local sections throughout the country hold periodic meetings which attract persons from other related professions. Individual AIHA members participate in conferences sponsored by other associations and serve on their committees. They also give freely of their time in developing manuals, standards and other industrial hygiene data for the benefit of other organizations.

FEW MEMBERS will question that the original intent of the objective as quoted has been, and is being, carried out. In fact, there are many who believe that far too much effort is being expended by our members for the benefit of other organizations, instead of developing basic industrial hygiene data as AIHA projects.

Another Association objective is "to correlate such activities as are conducted by individuals and agencies throughout industrial, educational, and governmental groups." While there may be several interpretations of the intent of this objective, it would appear that AIHA has made only limited progress in its fulfillment.

The Association has made no effort to study the problems and correlate significant data in the fields of Industrial Hygiene Chemistry, Air Pollution, Engineering, Radiation, and Toxicology. If industry or any other group is in need of information in these specialty fields, it cannot go to AIHA for the answers. Instead, it must take its problems to organizations other than AIHA—the same organizations which utilize individual members for the development of manuals and other basic industrial hygiene information. After 15 years of operation, the Association has only two technical committees—those concerned with Hygienic Guides and Noise.

This is not to suggest that we discontinue cooperation with other organizations having common interests with our own. Cooperation is essential, but we should strive to secure credit for AIHA in proportion to the contributions made.

THE AIHA should take the necessary leadership in correlating the technical and scientific aspects of industrial hygiene for the benefit of industry, labor, government, the public, and its own membership. One way to accept such leadership would be to establish technical committees in our specialty fields to study basic needs, and to develop accepted methods and other useful information for publication under the banner of AIHA. If the Association could become a clearinghouse for all types of industrial hygiene information, its position of leadership would be assured.

Consideration is now being given to the appointment of technical committees in our specialty fields. In the beginning, these committees will be asked to explore the needs in their respective fields and to outline programs for future action. I shall be pleased to hear from all of those members who would be willing to serve on these technical committees. It is sincerely hoped that significant progress can be reported in this page by March, 1955.

—HERBERT T. WALWORTH
President, AIHA

✦ Selected Titles and Abstracts

—FROM FOREIGN EXCHANGE JOURNALS

THE AMERICAN INDUSTRIAL HYGIENE ASSOCIATION receives several foreign journals in exchange for copies of the QUARTERLY. Selected articles from these will be abstracted in this and some future issues of the QUARTERLY. In addition, a partial list of articles, by titles and authors, will be presented. Additional information on any of the journals and articles may be obtained from: CARROL S. WEIL, Senior Industrial Fellow, Mellon Institute of Industrial Research, 4400 Fifth Avenue, Pittsburgh 13.

I. LA MEDICINA DEL LAVORO (ITALY). Vol. 45, No. 1 (1954).

Endogenous Pulmonary Hemosiderosis, A Disease Radiologically Mistaken for Pneumoconiosis. E. C. Vigliani, pp. 1 to 11.

Rudiments of the Substitution of Benzene with its Higher Homologues in Industry. M. C. Francone and L. Braier, pp. 29 to 32.

Considerations on the Behavior of the Electrocardiogram in Pulmonary Silicosis. C. Ceresa and F. Fedele, pp. 33 to 41.

II. THE JOURNAL OF SCIENCE OF LABOUR (JAPAN). Vol. 28, No. 12 (1952).

Experimental Studies of the Pathogenesis and Prevention of Chlorinated Naphthalene Poisoning. Shigeru Nomura, pp. 847 to 857.

Studies on Physiological Effects of Extremely High Temperature. Takeo Sukuki, pp. 858 to 868.

A Case of Acute Poisoning by Selenious Acid. Teruo Nakamura, pp. 886 to 888.

III. IBID. Vol. 29, No. 11 (1953).

Miners' (Coal) Cramps. Yoshihiko Sukuki, pp. 577 to 592.

Studies on Dust Respirators (Part 3)—Life of Dust Respirators used by Rock Drillers in a Metal Mine. Yasuo Oki, pp. 600 to 605.

A Survey on Industrial Lead Poisoning. Shinro Yamaga and Katsumi Saruta, pp. 606 to 609.

Acute Dermatitis in a Factory Producing Phthalic Anhydride. Toshimasa Kito and Kenichi Tosu, pp. 625 to 629.

IV. ANNUAL REPORT FOR 1952 OF THE INSTITUTE FOR SCIENCE OF LABOUR (JAPAN). Sept. 1953, No. 46.

Studies on Occupational Chronic Carbon Monoxide Poisoning. Juhko Kubota and Sumiko Ishizu (Laboratory of Occupational Disease), pp. 22 to 28.

Rats were exposed for a period of months to concentrations varying from 0.01 to 5% CO for 240 to 0.1 minute a day. Histopathological evidence of so-called chronic changes were found. These appeared to be accumulation of tissue changes resulting from these series of acute exposures. An initial increase of 20% to 40% in erythrocyte count was produced probably resulting from constriction of the spleen and mobilization of its reserve. This response was not repeated after a second exposure, even after a rest interval of 100 days.

Clinical symptoms of 583 "gas-workers" in five ammonium sulfate plants and two steel mills were followed for five years. Central nervous symptoms were seen—60% of the employees were conscious of increased forgetfulness and a smaller number reported numbness in the distal ends of the extremities.

Contrary to several other investigators, the authors found no increase in hemoglobin content or erythrocyte count in the men employed for long periods of time in these industries. In fact a general decrease in red blood cells, anemia, was found.

Visual function, as measured by the "visual field flicker test," was abnormal in many workers as was cardiac function, determined by E.C.G. Cardiac abnormalities, after exercise, was reported in 21 of 55 men examined.

Experimental Studies on the Tissue Reactions caused by Hard Soluble Materials and Some Discussions on the Prevention of Silicosis. T. Sano, pp. 29 to 32.

V. ARCHIV ZA HIGIJENU RADA (JUGOSLAVIA). Vol. 4, No. 3 (1953).

Experimental Infective Pneumoconiosis. E. J. King, C. V. Harrison, G. P. Mohanty, and D. A. Mitchison, pp. 289 to 300.

The Breathing of Pneumoconiosis-Producing Dusts. C. N. Davies (Medical Research Council, London), pp. 301 to 306.

Pneumoconiosis-producing dusts must be insoluble or have a very slow solubility. Dusts which cause long termed cumulative effects act by stimulating the growth of fibrous tissue (quartz), by producing mechanical injuries (asbestos, talc), or by accumulating large quantities of particles in the lymphatic system and throughout the lung (coal).

Another kind of risk from dust accumulating in the lungs arises from radioactive materials, particularly from solid products of radioactive decay of radon. An association between the normal content of radon in the atmosphere and lung carcinoma in the general population is possible.

Baritosis. M. Branisavjevic, Z. Kopac, G. Merkulov and S. Teofanovic, pp. 307 to 324.

The Pneumoconioses—Bricks in Search of an Architect. E. R. A. Merewether, pp. 365 to 382.

VI. IBID. Vol. 4, No. 29 (1953).

Diagnostic Significance of the "Lead Line." Zdenko Njemirovskij, pp. 500 to 510.

On Blood Lead Content and Urinary Coproporphyrin Relationship. Otto A. Weber and Fedor Valic, pp. 511 to 520.

Lesions of the Acoustic and Vestibular Apparatus in Workers Suffering from Mercury Poisoning. Zvonimir Krajina, pp. 529 to 536.

◆ News of the Local Sections

Ohio Valley Section

NEWLY ELECTED officers of the Ohio Valley Section are: President—ANDREW D. HOSEY, U.S.P.H.S., Division of Occupational Health; Vice-President—CHESTER H. ALLEN, Hilton Davis Company; Secretary-Treasurer—JIMMIE A. MARTIN, General Electric Company.

A joint meeting of the Ohio Valley Section, AIHA and the Cincinnati Radiation Society was held on February 15. The subject, "Legal Aspects of Radiation—New York State Code," was presented by HANSON BLATZ, Chief, Radiation Branch, Health and Safety Laboratories, New York Operations Office, Atomic Energy Commission.

Procter and Gamble Company was the host of the section at the May 13 meeting. A tour of the research laboratories was followed by the program: "Operation of the Miami Valley Laboratories"—DR. N. B. TUCKER, Associate Director of Research, Procter and Gamble Company; "Industrial Dermatitis Prevention," DR. H. W. LAWRENCE (Medical Aspects), L. J. BEAMAN (Industrial Hygiene Aspects).

Rocky Mountain Section

THE ROCKY MOUNTAIN SECTION held its annual meeting in Pueblo, Colorado on October 23. The election results were announced: President—H. F. SCHULTE, Los Alamos Scientific Laboratory; President-Elect—WILLIAM A. McGILVRAY, Julius Hyman and Company; Secretary-Treasurer—EVAN E. CAMPBELL, Los Alamos Scientific Laboratory.

The main speaker was P. W. JACOE, Occupational Health Section, State of Colorado Department of Public Health. His topic was "Industrial Health vs Industrial Development in the Colorado Springs-Pueblo-Denver Area." A motion picture, "The Story of Steel," was presented by HOWARD HILMES, Colorado Fuel and Iron Corp.

Washington-Baltimore Section

A MEETING of the Washington-Baltimore Section was held on December 16 at the Johns Hopkins Faculty Club. DR. ANNA M. BAETJER, Professor of Environmental Medicine, School of Hygiene and Public Health, Johns Hopkins University, spoke on "Impressions of South American Industrial Hygiene Programs."

Results of the annual election were announced: President—DR. WILMER H. SCHULZE, Baltimore City Health Department; Vice-President—DR. WILLIAM M. GAFAFER, U.S. Public Health Service; Secretary-Treasurer—CATHERINE W. BEAUCHAMP, Public Health Service, FSA.

Northern California Section

THE NORTHERN CALIFORNIA SECTION held a meeting on January 12 at the Officers' Club, Alameda Naval Air Station. DR. JAMES C. MALCOLM, Alameda County Health officer, and DR. W. ELWYN TURNER, Santa Clara County Health Officer, spoke on air pollution control activities in their respective counties. The results of the annual election were announced; President—RODNEY R. BEARD, M.D., Professor of Public Health and Preventive Medicine, Stanford University Medical School; President-Elect—BERNARD D. TEBBENS, SC.D., Associate Professor of Industrial Hygiene Engi-

neering, University of California; Secretary-Treasurer—GEORGE A. SHERMAN, Division of Industrial Safety, Department of Industrial Relations, San Francisco, California.

A section meeting on March 9 was held in Oakland, California. Two papers were presented: "Industrial Wastes"—ERMAN PEARSON, Professor, University of California College of Engineering; "Atmospheric Hydrogen Sulfide Studies of East Bay Municipal Utilities District"—GERSON CHANIN, Chemist, East Bay Municipal Utilities District.

Gulf Coast Section

AN ALL-DAY session of the Gulf Coast Section was held at Kelly Air Force Base on January 23. The morning was devoted to a tour of the plant facilities and operations. The afternoon session was moderated by MARTIN C. WUKASCH, Texas State Department of Health. The following papers were presented: "The Psychotic in Industry"—CAPT. LAWRENCE T. SMYTH, USAF (MC), Preventive Medical Officer, Kelly Air Force Base; "Noise and its Control at Kelly"—EDWARD W. POTH, Senior Industrial Hygiene Consultant, San Antonio Air Materiel Area; "The Industrial Medical and Health Program at the Victoria, Texas Plant"—DR. G. E. MCGLOTHEN, Medical Director, E. I. Du Pont de Nemours and Company; "Biological Tests for Industrial Hygiene Evaluations"—J. W. HAMMOND, Industrial Hygienist, Humble Oil and Refining Company.

A dinner was held in the evening. The speaker was LT. COL. JOHN BOYSEN, USAF (MC), Deputy Surgeon, Air Materiel Command. His subject was "The Industrial Medical Program in the United States Air Force."

At a business meeting preceding the afternoon session the following officers were elected: President—DR. CARL U. DERNEHL, Carbide and Carbon Chemical Company; President-Elect—JACK NEAL, University of Texas Medical College, Galveston Branch; Secretary-Treasurer—J. W. HAMMOND, Humble Oil and Refining Company.

Chicago Section

THE CHICAGO SECTION held its March meeting in Milwaukee, Wisconsin at the Pabst Brewing Company. New officers were elected at this meeting. President—JOSEPH A. HUBATA, M.D., Armour Research Laboratories; President-Elect—WILLIAM T. MCCORMICK, Inland Steel Company; Secretary-Treasurer—FLOYD A. VAN ATTA, Ph.D., National Safety Council.

The April meeting was held in Chicago. DR. R. H. WILSON, Medical Director, B. F. Goodrich Company, spoke on "Health Maintenance Program in the Rubber Industry."

St. Louis Section

THE ST. LOUIS SECTION AIHA held a joint meeting with the St. Louis Section AAIN on March 30. "Arthritis and Rheumatism in Industry," was the subject of the speaker, DR. HENRY ROSENFELD, Medical and Scientific Committee, Eastern Missouri Chapter, Arthritis and Rheumatism Foundation.

✦ *In the News*

AMOS TURK, Ph.D., former Director of Research and Development for the Connor Engineering Corporation, has established an office in Danbury, Connecticut as a Consulting Chemist. Special attention is directed to analysis and control of atmospheric pollutants and odors.

JOSEPH A. HUBATA, M.D., who has been Associate Medical Director of Armour Laboratories on special assignments, has been appointed Acting Medical Director.

EDWARD C. J. URBAN, M.S.E., became Associate Professor, Department of Industrial Hygiene and Medicine, College of Medicine, Wayne University on April 1. For the past 15 years, MR. URBAN has been Industrial Hygiene and Research Engineer for the Saranac Laboratory and the Trudeau Foundation.

Hygienists Wanted

THERE are openings for industrial hygiene engineers in Venezuela, Brazil and Mexico City. Appointments may be either Civil Service or commission in the Public Health Service Reserve Corps. Interested persons should write to the Surgeon General, U.S. Public Health Service, Division of International Health, Fourth and Independence Avenue, S.W., Washington 25, D.C.